OLOGY DEPARTMENT

PUBLIC LIBRARY
AUG 19 1947
DETROIT

Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

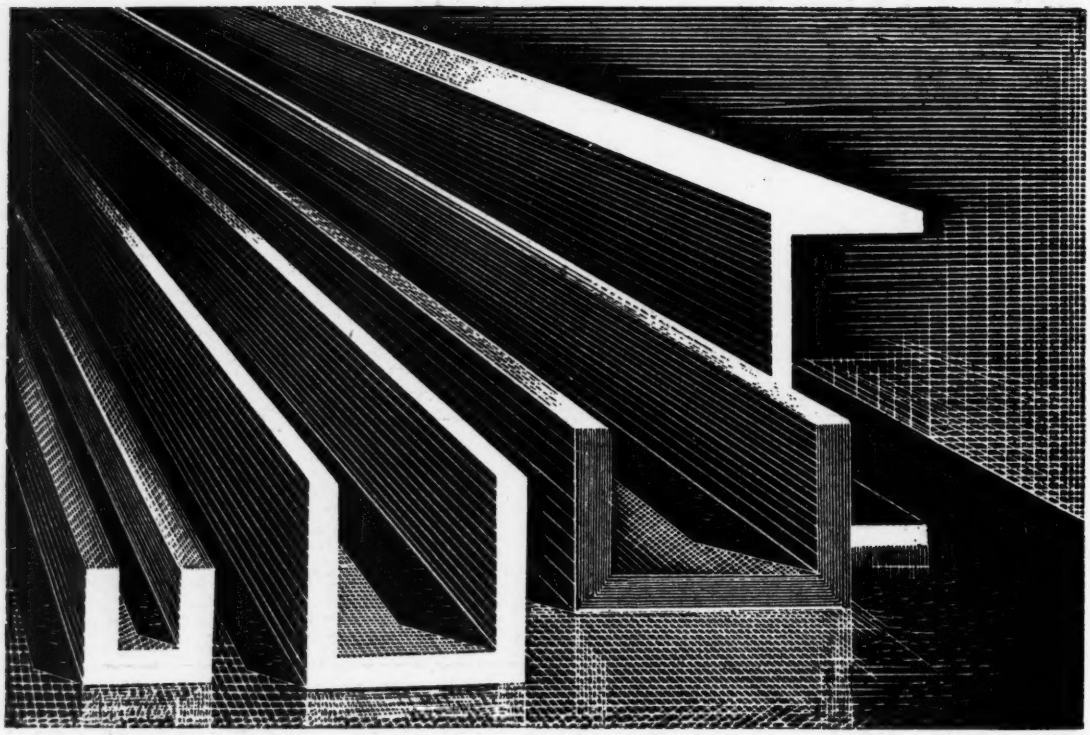
The Design of a Synchrodyne Receiver — Part I.

Radio Interference from R.F. Heating Equipment

A Wide Range Audio Oscillator

Electrical Analogue Computing — Part 3

2/- AUG., 1947



this is CHANNEL TUFNOL

a material for engineers

Channel Tufnol is particularly useful where strength is required. The laminated structure is continuous along the sides and base, thereby ensuring constant strength in all directions. Channels are made in lengths of approximately 48″ and in sizes $\frac{3}{8}$″ x $\frac{3}{8}$″ x $\frac{3}{8}$″ up to 2″ x 2″ x 4″ with wall thicknesses of from $\frac{1}{16}$″ up to $\frac{3}{8}$″.

Tufnol Channels are light, are electrical insulators, resist corrosion, and can be machined easily.

Other forms of Tufnol include sheets, tubes, rods, bars and angles.

Examples of components made from Tufnol Channel : brackets, bus-bar insulators, guides, supports.

An ELLISON Product

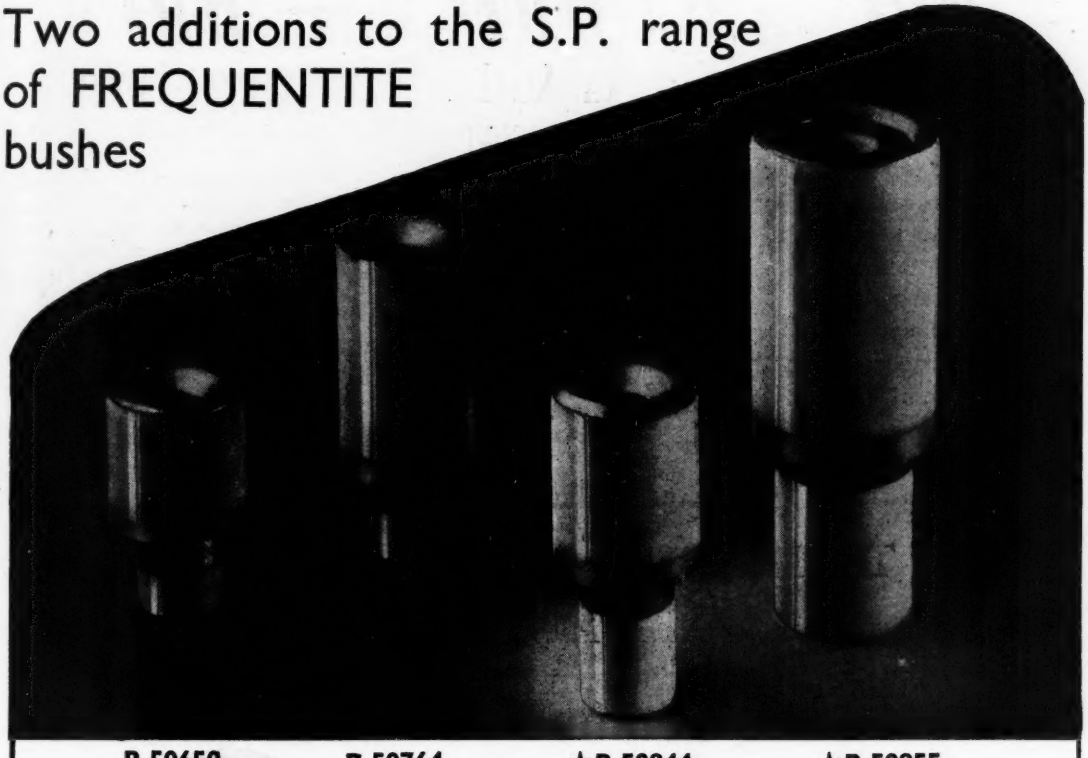
TUFNOL LTD

PERRY BARR BIRMINGHAM 22B

152

METALLISED CERAMICS

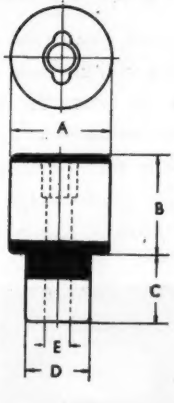
Two additions to the S.P. range of FREQUENTITE bushes



R.50650 R.50764 ★R.50844 ★R.50855

TYPE	A mms.	B mms.	C mms.	D mms.	E mms.
R.50650	9·5	9·5	6·4	6·25	2·75
R.50764	9·5	16·7	6·4	6·25	2·75
★R.50844	9·5	12·7	9·5	6·25	2·75
★R.50855	12·7	22·2	12·7	9·5	3·9

★ Recent additions to the range



For full information and prices please write to :

STEATITE & PORCELAIN PRODUCTS LTD.

STOURPORT ON SEVERN, WORCS. Telephone: Stourport III. Telegrams: Steatain, Stourport.

S.P.43

WHY

IRON POWDER?

To improve the performance of inductances; to permit a smaller coil to be used and thereby to decrease manufacturing costs; to vary easily the inductance of coils by means of movable powder-iron cores; to pre-set fixed inductances to accurate limits.

WHY

CARBONYL IRON POWDER?

Because the carbonyl process produces a powder with the appropriate characteristics required by core-makers. Because each particle is spherical and the powder has therefore a high packing density, and is easily insulated. Because no heat treatment at high temperatures after pressing is required.

WHY

TWO GRADES?

Because two grades cover the majority of requirements.
Grade ME is very fine and hard, spherical and remarkably uniform; primarily suitable where electromagnetic losses are required to be very small, and especially for high-frequency applications.
Grade MC is also fine and spherical but is softer and therefore more easily compressible. Useful in cases where higher permeabilities are required. Further information freely given on request.

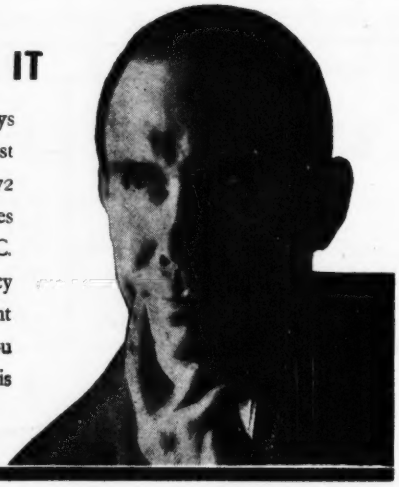
The Mond Nickel Company, Limited

Grosvenor House, Park Lane, London, W.1

13B/M/1

A GOOD GUESS WILL NOT SOLVE IT

A good guess may sometimes help, but it will not always find a difficult fault in a wireless set. The easiest and quickest way to locate the trouble is to use a Weston Model E772 Analyser which is designed for systematic analysis. Its features include high sensitivity—20,000 ohms per volt on all D.C. ranges—wide range coverage, simplified controls, accuracy and robust construction. You will find this instrument universally useful—it will save you time, trouble and money and it is really reliable — it's a Weston.



ANALYSE SYSTEMATICALLY WITH A **WESTON**

SANGAMO WESTON LTD. ENFIELD, MIDDX. Telephone: Enfield 3434 & 1242

WHERE EXTREME ACCURACY IS REQUIRED

Made in Three Principal Materials

FREQUELEX
An insulating material of Low Di-electric Loss, for Coil Formers, Aerial Insulators, Valve Holders, etc.

PERMALEX
A High Permittivity Material. For the construction of Condensers of the smallest possible dimensions.

TEMPLEX
A Condenser material of medium permittivity. For the construction of Condensers having a constant capacity at all temperatures.

Bullers

CAN SATISFY THE MOST EXACTING CUSTOMER

BULLERS LOW LOSS CERAMICS

BULLERS LTD., 6, Laurence Pountney Hill, London, E.C.4.
Telegrams: "Bullers, Cannon, London."
Phone: Mansion House 9971 (3 lines)

W. ANDREW BRYCE & CO. LTD.
W.A.B.

Hermetically Sealed

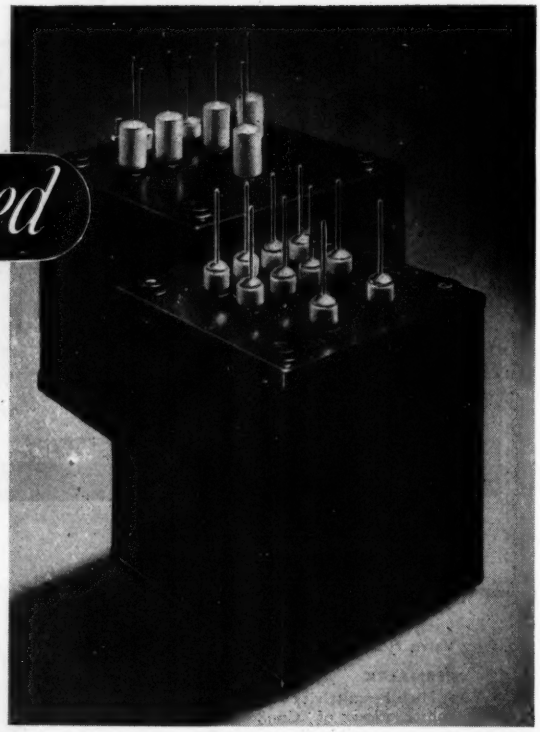
TRANSFORMERS

W.A.B. Hermetically Sealed Transformers were developed during the war to meet the requirements of the Services for a unit which would operate continuously under conditions of high relative humidity and high ambient temperature.

A patented method of internal construction ensures that the weight of the Transformer is taken directly on the fixing bushes and not on the case, thus preventing a risk of damage to the sealing of the case when the unit is subjected to mechanical shock.

All Transformers in this range are so constructed that they can be used for either chassis or baseboard mounting.

W. ANDREW BRYCE & CO. LTD.
SHENLEY ROAD, BOREHAM WOOD, HERTS
Telephone: ELStree 1870, 1875 and 1117



TOROIDAL
POTENTIOMETERS
10-1000 WATTS

Ceramic Insulation only—and approved for Tropical conditions.
Complete Ceramic Rings for strength.
Approved by all Government Departments.
Reasonable Delivery.

Specialists in ALL TYPES OF TOROIDAL WINDINGS

P. X. FOX LIMITED
HORSFORTH • YORKSHIRE • ENGLAND
Telephone: Horsforth 2831 Telegrams: Toroidal, Leeds

ELECTRONIC
CONTROL

SUNVIC

HIGH ACCURACY

RESISTANCE THERMOMETER CONTROLLER

FOR CREEP TESTS, ETC.

This is a purely electronic controller giving an output proportional to the deviation of the temperature from the desired value. It operates up to 800° C. with a platinum resistance-thermometer. Sensitivity one part in 5000. Primarily developed to control the temperature of creep test specimens, the SUNVIC RESISTANCE THERMOMETER CONTROLLER is suitable for high accuracy work within the range covered by platinum and nickel resistance thermometers. For details, please request technical publication RT 10/16.

SUNVIC CONTROLS LTD.
Stanhope House,
Kean Street,
London, W.C.2.

TAS/SC 117

MYCALEX
THE INSULATOR

May solve your INSULATION PROBLEMS

with the following UNIQUE COMBINATION OF PROPERTIES

HIGH DIELECTRIC STRENGTH ● NON-ABSORBTIVE LOW-LOSS FACTOR ● HEAT RESISTING ● MANUFACTURED TO CLOSE TOLERANCES ● NON-TRACKING ● RESISTANT TO FUNGUS GROWTH ● WILL NOT SHRINK OR WARP LOW EXPANSION ● CO-EFFICIENT

MACHINED TO CUSTOMER'S REQUIREMENTS OR AVAILABLE IN SHEETS AND RODS.

Also makers of INGRAM-MYCALEX Capacitors utilising MYCALEX as a dielectric with plates moulded in, to form a sealed unit.

Phone CIRENCESTER 400 or SEND ENQUIRIES TO

MYCALEX COMPANY LIMITED

ASHCROFT ROAD, CIRENCESTER, GLOS.

MY 15

TELCON RF CABLES

for all Television and Radio Requirements

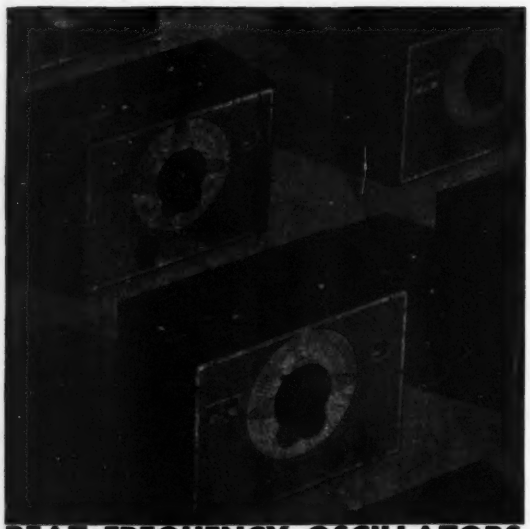
CABLE CHARACTERISTICS

CODE	Zo	CAPACITY	ATTENUATION
AS44 D.S.T.A.	90— 102	12.5 μμ F per foot.	At 10Mc/s 0.13 db/100 Ft. At 100 Mc/s 0.44 db/100 Ft.

DIAMETER:—2.22 ins. **TYPE**:—DISC SPACED AIR DIELECTRIC LEAD SHEATHED ARMOURED

Further details of this and other R.F. Cables on application

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO. LTD.
Founded 1864
Head Office: 22 OLD BROAD ST., LONDON, E.C.2. Tel: LONdon Wall 3141
Enquiries to TELCON WORKS, GREENWICH, S.E.10. Tel: Greenwich 1040



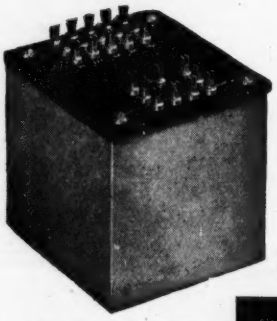
BEAT FREQUENCY OSCILLATORS

LELAND INSTRUMENTS LTD

—for priority requirements only, at present. Write for particulars stating frequency range required.

21, JOHN STREET, BEDFORD ROW, LONDON WC1
TELEPHONE: CHANCERY 8760

Power & Audio Frequency Transformers



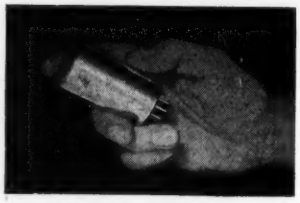
POWER TRANSFORMERS
5VA to 5KVA
Audio Transformers up to 1500 watts
EITHER

- Open construction in a variety of mountings, windings vacuum pressure impregnated and varnished sealed.
- Canned and bitumen or wax filled.
- Hermetically sealed, oil filled, with pressure compensation.

Application : Microphone, driver, anode to line, line to line, etc.

SPECIAL FEATURES

- Direct fixing to Transformer structure — no strain on container to cause distortion or leaks.
- No unsightly fixing lugs external to container.
- Male or female threads for upright or inverted mounting at will.



AUDIO TRANSFORMERS—SINGLE, DUAL OR TRI-ALLOY SHIELDED, GIVING NOISE SUPPRESSION UP TO 90 DB RELATIVE TO CONVENTIONAL OPEN ASSEMBLIES.

Associated Electronic Engineers, Ltd.
Dalston Gardens, Stanmore, Middlesex.
Tel. : WORDSWORTH 4474/5/6
e.h

Inspect at Speed!

★ *SEE WHAT IS HAPPENING WITHOUT STOPPING FAST* ★ *RUNNING MACHINERY*

By installing a **Scophony Electronic Stroboscope** detailed inspection of all moving parts can be made without slowing or stopping machines ; or interfering with production in any way. The Stroboscope is a highly sensitive instrument which arrests visual motion, thus allowing the effect of vibration, bounce and wear to be observed in all rotating and reciprocating mechanisms. ★

Such inspection saves sudden breakdowns and gives a truer appreciation of " cause and effect " in all types of machinery. ★

The **Scophony Stroboscope** is the wonder of this mechanical age and no wise maintenance engineer can afford to be without one. It is indispensable in mills, factories, garages, research laboratories, locomotion and a host of other places ★

—*it's another* SCOPHONY PRODUCT

SCOPHONY LTD.

36 VICTORIA STREET · LONDON · S.W.1

Telephone : ABBEY 4852

For Scientific problems, Scophony is at your service

Muirhead Magslips

For Measurements and Controls where you want them

Designed by the Admiralty Research Laboratory and so widely used for war time service applications, these devices are now available for all. Muirhead Magslips, which are backed by twelve years of manufacturing experience, may well solve many of your remote control and indication problems.

Details in Bulletin B-580, sent on request.

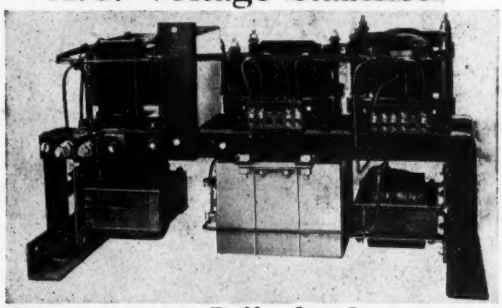
MUIRHEAD

Muirhead & Co. Limited. Elmers End, Beckenham, Kent. Telephone: Beckenham 0041-2.

FOR OVER 60 YEARS
DESIGNERS AND MAKERS OF PRECISION INSTRUMENTS

CRC 57d

FREQUENCY-COMPENSATED
A.C. voltage stabiliser



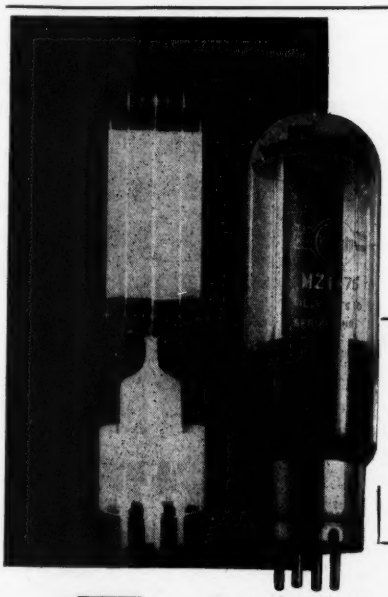
The type "B" dual-purpose
"STABILISTOR"

This is a special FREQUENCY AND VOLTAGE-COMPENSATED A.C. Voltage Stabiliser providing two different outputs, which are available alternatively, but not simultaneously.

OUTPUT No. 1 is FREQUENCY AND VOLTAGE-COMPENSATED at the exact resistive load stated. Any desired output voltage can be provided, and this must be specified when ordering. The output is isolated from the input by means of a double-wound transformer, and the output waveform is sinusoidal.

OUTPUT No. 2 is VOLTAGE AND LOAD-COMPENSATED. The output voltage is 230 volts and any fixed or variable load from zero up to the rated load may be supplied.

WESTINGHOUSE BRAKE & SIGNAL Co. Ltd.
82, YORK WAY, KINGS CROSS, LONDON, N.1.



For modulation and L.F. amplification
HERE'S A BETTER VALVE

All things being equal, the real measure of a valve's performance is the length of time it will operate with undiminished efficiency. In this respect the MZ1-75 scores heavily. Like all Mullard transmitting and industrial valves, it has been designed with an eye to cost per life-hour.

Modern manufacturing methods ensure its reliability and offer the additional advantage that all valves of the same type are characteristically consistent. The long-life, oxide-coated filament is unaffected by fluctuations in the mains supply, and also permits operation at an economical anode voltage.

A glance at the data panel with these factors in mind will explain why the MZ1-75 wins the approval of communications engineers who want a better valve for modulation and L.F. Amplification.

MZ1-75
OUTPUT OR MODULATOR TRIODE

Vf	10.0V
If	1.6A
Typical operation for two valves in class AB2 push-pull	
Va	1250V
Ia (no sig.)	2x40mA
Ia (Max. sig.)	2x157mA
W out	260W
D tot	2.3%

Mullard

For further developments watch

Technical data and advice on the applications of the MZ1-75 Triode can be obtained from

Mullard
THE MASTER VALVE

THE MULLARD WIRELESS SERVICE CO. LTD., TRANSMITTING AND INDUSTRIAL VALVE DEPARTMENT, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

(MVT161D)

Modern Miniatures by Mazda

A completely new range of high efficiency Miniature Valves has been introduced by MAZDA to meet the requirements of the Electronic Engineer.

THE EDISON SWAN ELECTRIC CO. LTD., 155, CHARING CROSS ROAD, LONDON, W.C.2.

Edit

Tele

The

An

A V

The

A M

Rad

A

and

Gover

small

earnes

work

succes

improv

someti

the ge

but ve

tion o

pounde

someo

ground

How

researc

worke

over a

clearin

to say

clearin

TELEPHONE :
CENTRAL 6565
(10 LINES)

Electronic Engineering

INCORPORATING TELEVISION AND SHORT WAVE WORLD

TELEGRAMS:
LECTRONING
ESTRAND
LONDON

MANAGING EDITOR G. PARR, M.I.E.E.

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 28, ESSEX STREET, STRAND, W.C.2.

Monthly (published last day of preceding month) 2/- net. Subscription Rates: Post Paid to any part of the World—6 months, 13/- ; 12 months, 26/-. Registered for Transmission by Canadian Magazine Post.

CONTENTS

Editorial—Duplication 239

Television Relay 240

The Design of a Synchrodyne Receiver—Part I
By D. G. Tucker, Ph.D., A.M.I.E.E. 241

An E.H.T. Supply for Television Receivers
By C. H. Banthorpe 245

A Wide Range Audio Oscillator
By F. W. Dawe, A.C.G.I., M.I.E.E. 246

The N.P.L. Exhibition 248

A Method for the Measurement of Small Direct Currents
By E. J. Harries, Ph.D. 249

Radio Interference from Industrial R.F. Heating Equipment
By A. Turney, B.Sc. 251

A Frequency Modulated, Multi-channel V.H.F. Radio Link
By E. S. Teltscher, B.Sc. 256

Electrical Analogue Computing—Part 3
By D. J. Mynall, B.Sc., A.M.I.E.E. 259

Mersey Harbour Radar 263

Carbon Black, Its Types, Properties, and Uses
By G. FitzGerald Lee 265

Notes from the Industry 266

Television Commentary 267

Book Reviews 268

Abstracts of Electronic Literature 270

Correspondence xvi

Duplication

ALL over the country there are hundreds of research laboratories, from the well-equipped and directed organisations of the Government and larger firms to the small back rooms with two or three earnest workers. Day after day the work goes on, sometimes with a successful utilitarian ending—the improvement of a product or process, sometimes with a bit more added to the general catalogue of knowledge, but very often ending in the confirmation of what has already been propounded, or with the realisation that someone else has already covered the ground more thoroughly.

How many of the minor projects of research are duplicated? How many workers are wasting their time going over a trail already blazed instead of clearing a fresh path? It is impossible to say without the aid of a central clearing-house of information—a sort of super-library where every item is classified and where the would-be researcher can learn that his project has already been started by Mr. Jones of Stockport and that the results will be along next week.

And why stop at Britain? Why not have an International Clearing House of Research and do away with all duplicated effort? The next step would be an International Directorate of Research which would eventually hand out assignments and chase up outstanding work. . . . One is almost afraid to suggest such a scheme for fear of putting ideas into the heads of the bureaucracy, assuming it to be possible.

It seems, then, that some duplication is unavoidable and may even be desirable as a check on some particularly revolutionary finding. But it will be agreed that there is no excuse for wilful duplication—the waste of time and energy by starting a job without having found out the background.

The reading-up of previous work on the subject is in many cases looked on as a tedious instead of an essential preliminary.

The excuse is often made that, except in London, adequate library facilities are not available. This is probably justified, and one of the stimuli to better research would be the provision of more centres of technical information in the country. The Science Library and the Patent Office Library should have their counterparts in every principal town, but while the technical libraries are few the only alternative is to regard the time spent on searching as a vital part of the whole project, and plan accordingly.

Television Relay — *Television Wireless Link Demonstration by the Marconi Co., Ltd.*

THIS equipment has been designed to provide a suitable link for point-to-point distribution of Television signals. Such a link has been set up between Danbury Hill, near Chelmsford, which is 31½ miles from A.P., and Great Bromley, near Colchester which is 24 miles from Danbury Hill. The intervening terrain is substantially flat and there is an optical path between the transmitting and receiving aerials.

Signals from A.P. are received at Danbury Hill, and after demodulation the sound and video signals are used to modulate two F.M. transmitters, one for sound, the other for vision. The vision transmitter has an output of 5 watts and a maximum frequency of 3 Mc/s. The sound transmitter has an output of $\frac{1}{10}$ watt and a maximum frequency deviation of 300 kc/s. Both transmitters operate in the 500 Mc/s. band. The transmitting aerials are about 40 feet from the ground. The sound aerial is an 8-element array and the vision aerial is a dipole energising a horn-type radiator. The horn, which is shown below, is about 3 ft. 6 in. square at the mouth, and about 7 ft. long.

The use of F.M. for vision is particularly interesting, in that it has been suggested that multi-path distortion effects would be more severe than in the case of A.M.

In this equipment no trouble from this cause has been observed, presumably owing to the high aerial gains which are employed, which must attenuate signals arriving by other than the direct optical path. Furthermore, the relatively low deviation ($\pm$ 3 Mc/s.) results in a sideband spectrum only about 10 Mc/s. wide, so that any multi-path distortions would be less than would be produced by a large deviation.

At the demonstration excellent pictures from an outside broadcast at Ascot were shown, with no deficiencies which could be attributed to the link.

The demonstration was of particular interest owing to the recent announcement of the B.B.C. that they have placed a contract with the Marconi Company for the sound and vision transmitters for a new television station on a site yet to be decided. The method of modulation used in the sound transmission is the subject of a recent Marconi patent, in which the frequency of a quartz crystal is controlled by the application of the sound voltages to the circuit. This method represents a big advance in technical performance and is to be incorporated in the new 25 KW. frequency-modulated broadcasting transmitter now under construction for the B.B.C. in the Marconi Company's Chelmsford Works.

J.L.B.

Left) Close-up of receiving aerial with paraboloid reflector, on mast at Great Bromley.

(Right) Mast at Great Bromley carrying sound and vision aerials, which can just be seen on the lower platform.

(Inset) Vision transmitting aerials at Danbury Hill.

The Design of a Synchrodyne Receiver

Part 1.—Design Principles

By D. G. TUCKER, Ph.D., A.M.I.E.E.*

THE article on the Synchrodyne circuit in the March issue† has apparently appealed to many readers who have either a desire to try out a new system for its inherent interest, or an enthusiasm for more perfect reception. From both types of reader many letters have been received requesting further information, and the present article therefore attempts to give all the information needed by a radio engineer or technician to enable him to construct a receiver for himself. In this first part the design principles will be discussed, so that it is clearly understood what functions the various parts of the circuit perform; and in the second part some actual designs will be described.

It should be clear from the preliminary article that the main features which distinguish the synchrodyne from other systems of reception are:

(a) The separation of the requirements regarding selectivity and quality, so that each can be adjusted independently of the other.

(b) The permissible absence of tuning from the radio-frequency portion of the circuit.

(c) The consequent necessity for demodulation without the non-linearity of response normally inherent in detectors.

(d) The synchronisation of the demodulating oscillator to the incoming carrier frequency.

Feature (a) means that both selectivity and quality can be very high; (b) means that ganging and tracking troubles are eliminated; (c) is a requirement of fundamental importance, since, owing to the absence of R.F. tuning, all signals on the aerial are transmitted through the circuit, and would become demodulated by rectification if any non-linearity were present. The system of demodulation used must therefore be a "linear" one; this is more fully explained later. Feature (d) is the factor having the greatest effect on the actual use of the receiver, for it gives a quite different behaviour from superheterodyne and straight receivers in the tuning-in process, owing to the beat-note produced as synchronisation is approached. The greatest part of the discrimination against unwanted signals is due to the synchronised oscillator portion of the receiver, and its design and adjustment is therefore critical.

It can be seen that the aspects of design of the synchrodyne receiver which are not covered in design procedures for other systems are those of linearity and synchronisation. These are therefore the main subjects of this part of the article.

2. The demodulation of a signal by multiplying it by a frequency equal to its carrier frequency

At this stage it is desirable to give briefly an account of the mechanism of demodulation. The incoming signal is transmitted through the demodulator circuit, to which the demodulating tone is applied in such a way as to vary the loss of the circuit according to its own instantaneous voltage. The input signal is thus "multiplied" by the demodulating signal.

Let the incoming modulated signal be:

$$E_1 \sin \omega_c t\,[1 + k \sin \omega t] \quad \ldots\ldots\ldots (1)$$

where E_1 is the average amplitude (or carrier amplitude) of the modulated signal,

ω_c is the angular frequency of the carrier,

k is the depth-of-modulation factor,

ω is the angular frequency of the modulation.

The demodulating tone is of frequency ω_c, but it may have a phase angle θ relative to the carrier of the input signal. Let it be, therefore, $E_2 \sin(\omega_c t + \theta)$.

The output from the demodulator is then proportional to the product, *i.e.*, to:

$$E_2 \sin(\omega_c t + \theta)\, E_1 \sin \omega_c t\,[1 + k \sin \omega t]$$

although in certain types of modulator, the value E_2 has no significance and should be replaced by unity.

This output can be expanded into the following:

$$\frac{E_1E_2}{2}\left[\cos\theta - \cos(2\omega_c t + \theta) + k\cos\theta\sin\omega t - \frac{k}{2}\sin(2\omega_c t + \omega t + \theta) - \frac{k}{2}\sin(2\omega_c t - \omega t + \theta)\right] \quad (2)$$

In this expression, all terms are of supersonic frequency except:

$$\frac{E_1E_2}{2}[\cos\theta + k\cos\theta\sin\omega t] \quad \ldots\ldots (3)$$

which is therefore all we have to consider.

The output term

$$\frac{E_1E_2}{2} k\cos\theta\sin\omega t$$

represents the required output of modulation frequency with an amplitude term proportional to $\cos\theta$.*

The output term $\frac{E_1E_2}{2}\cos\theta$ represents a D.C. output of amplitude also proportional to $\cos\theta$. Since the output of D.C. is proportional to the output of modulation frequency, it can be used for A.V.C. purposes.

Any unwanted input signal will have a frequency ω_u different from ω_c, and will produce an output frequency equal to the difference $\omega_u - \omega_c$, which will, in general, be supersonic and eliminated by the audio stage (which may include a low-pass filter as shown in the preliminary article—but this is not always necessary).

It is now clear how the wanted signal is selected and demodulated to audio-frequency without any process of rectification or R.F. selectivity.

3. The synchronising process

In the previous section we have assumed a demodulating frequency ω_c equal to the wanted carrier. We know this is obtained from an oscillator synchronised to the carrier by injection of some of the input signal into the oscillator circuit. In order to design and adjust the circuit correctly, it is necessary to know something of the behaviour of

* P.O. Research Station, Dollis Hill.

† P. 75.

* The angle θ is the phase angle of the output of the synchronised oscillator relative to the incoming carrier. It will be seen from Section 3 and Fig. 3 that it can vary from $-90°$ to $+90°$; but over most of the frequency-range of synchronisation it varies only fairly slowly, and we can assume that variations outside the range $-60°$ to $+60°$ will very rarely occur. This means that a variation of about 2 : 1 may occur in the amplitude of the demodulated signal; this is not very serious.

synchronised oscillators, more particularly in regard to the voltages to be used in the input and oscillation circuits. The voltage relationships determine not only how easily and stably the oscillator will synchronise, but also how pure a tone will be obtained from the output. A detailed account of these matters can be obtained in the published papers referred to in the preliminary article. In the following paragraphs no more than a brief outline will be given.

3.1 Synchronisation with a pure injected tone

For simplicity we will consider first of all the case of a single tone injected into the grid circuit of the typical oscillator shown in Fig. 1. The mechanism by which an injected signal is able to synchronise an oscillator is entirely a function of the non-linear properties of the oscillator circuit. All oscillators contain at least one element having a characteristic which varies with amplitude; without this their operation would be impracticable, since any oscillation once started would build up to an infinite amplitude. In Fig. 1 the valve serves as both maintaining and non-linear elements. If a tone of frequency f_s is injected into the grid circuit, where f_s is very near the natural oscillation frequency f_o, then there is a large amount of positive feedback to this frequency, and the amplification to the frequency f_s is in consequence very high. Thus a very small input voltage may result in a large voltage on the grid. The presence of this voltage may so reduce the amplification of the valve (owing to its non-linearity) that the natural oscillation can no longer take place, and only the "forced" oscillation at frequency f_s remains. The oscillator is now said to be synchronised, since its output frequency is identical with the control frequency.

Fig. 2 shows a vector diagram of the voltages now concerned in the grid circuit. E_F is the voltage fed back via the tuned circuit, E_G is the resultant grid voltage, and E_S is the injected synchronising voltage. For equilibrium, the condition is evidently that the vector sum of E_F and E_S must equal E_G. Let the angle between E_S and E_G be θ. Let also the grid amplitude of the natural oscillation (in the absence of the injected signal) be E_{G0}. Then it can be shown that there are two conditions determining whether or not the free oscillation will be suppressed, *i.e.*, whether or not the oscillator will remain synchronised. These conditions are that, for synchronisation,

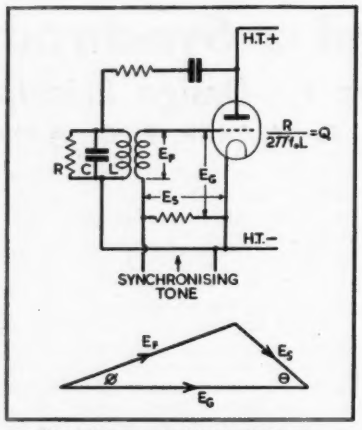


Fig. 1 (above). Feedback Oscillator.
Fig. 2 (below). Vector diagram for synchronised oscillator.

$$E_G > \frac{1}{\sqrt{2}} E_{G0} \quad \ldots\ldots\ldots\ldots \quad (4)$$

and

$$-\frac{\pi}{2} < \theta < \frac{\pi}{2} \quad \ldots\ldots\ldots\ldots \quad (5)$$

Synchronisation will fail when either of these conditions becomes an equality. It can be shown that the first then applies for large injected voltages, the second for small. In practice, only the second is likely to be encountered.

Thus synchronisation may be said to fail when the phase angle between the injected signal and the grid voltage becomes 90°. This condition is known as pull-out, and will be dealt with again later. Pull-in is, of course, the converse phenomenon.

3.2 The chief properties of a synchronised oscillator

It is thus seen that the phase angle θ between controlled and controlling signals may vary over a range of ± 90° without pull-out. The manner in which the angle varies between one limit and the other is given by the relation

$$\sin\theta = \frac{E_G}{E_{G1}} \cdot \frac{f_o - f_s}{f_o - f_{s1}} \quad \ldots\ldots\ldots\ldots \quad (6)$$

where the suffix "1" indicates the value at pull-out. If the oscillator is working very non-linearly, or if the injected voltage is very small, E_G and E_{G1} are very nearly equal, and the graph of θ against frequency difference $(f_o - f_s)$ is a sine curve, as shown in the example of Fig. 3.

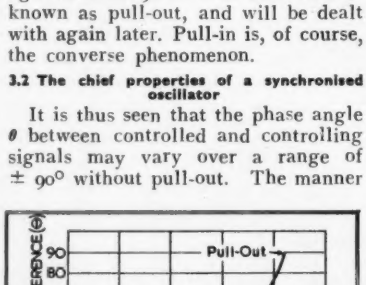


Fig. 3. Variation of phase angle in synchronised oscillator.

In general, the output voltage of the oscillator is not constant over the synchronising frequency range. It is a maximum at the point where $f_o = f_s$ and a minimum at pull-out. It is difficult to define this variation by a simple mathematical expression, but Fig. 4 illustrates it with some actual observed values. The variation is smaller with small values of injected voltage, and with large natural amplitudes (*i.e.*, with a large degree of non-linearity). The lack of symmetry, which is quite noticeable, is due to the shift of natural frequency caused by harmonics.

A most important relationship is readily deduced from the vector diagram of Fig. 2. At pull-out, E_S is perpendicular to E_G. If ϕ is the angle between E_F and E_G, then, at pull-out

$$\frac{E_{S1}}{E_{G1}} = \tan\phi$$

where the suffixes "1" are again used to indicate pull-out values. Now, if the tuned circuit of the oscillator has a value of reactance/resistance ratio equal to Q, then it is readily shown that near resonance,

$$\tan\phi = 2Q(f_o - f_{s1})/f_o$$

assuming f_o is the resonant frequency of the tuned circuit as well as the natural frequency of the oscillator. Therefore

$$E_{S1} = 2Q \cdot E_{G1}(f_o - f_{s1})/f_o \quad \ldots\ldots \quad (7)$$

This equation enables the required injected voltage to be calculated for any given oscillator and for any required range of synchronised frequencies. In practice, the natural frequency will drift, and enough controlling signal must be injected to ensure that synchronism is maintained over the whole range of drift. The synchronised frequency range is seen to be proportional to the injected voltage.

When pull-out does occur, the natural oscillation is not, in general, recommenced, but beats set in at a

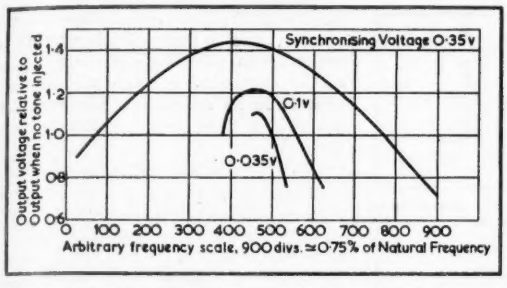


Fig. 4. Variation of output voltage of synchronised oscillator, over synchronised frequency range.

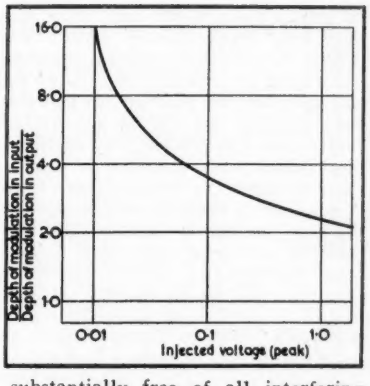


Fig. 5. Reduction in depth of modulation due to synchronised oscillator.

frequency lower than the difference between natural frequency and injected frequency. When the oscillator is only just pulling out, they are very slow, and appear as a sudden slip of one cycle in between two periods of synchronism. As the oscillator is detuned more and more, the beats become more rapid, and eventually the beat frequency is equal to the difference between natural and injected frequencies.

3.3 Synchronisation with a modulated injected signal

In the synchrodyne circuit, the injected signal is modulated; in other words, the amplitude of the synchronising signal varies. The effect of this on the range of frequencies over which synchronism is maintained can be seen by assuming the modulation is only slowly varying relative to the carrier—a condition which applies in practice. If the natural oscillation frequency has drifted too far from the injected carrier, then pull-out will occur at the troughs of the modulated waves, although the peak amplitude may be sufficient to maintain synchronism. It is clear, therefore, that the synchronised range is reduced when the injected signal is modulated. If the modulation were 100 per cent. or more, then imperfect synchronisation would be obtained, but in practice this occurs on only very occasional peaks, and causes no trouble.

The output of the oscillator contains very little of the modulation. The reduction of depth of modulation in the oscillator is due to the non-linear regenerative characteristics of the circuit, and is greatest when the injected signal is smallest. A typical relationship is shown in Fig. 5, which gives the reduction in depth of modulation at various voltages of the injected signal for an oscillator using a small H.F. pentode oscillating at about 1 volt peak grid amplitude. It can be seen that if the injected voltage is kept small, the output of the oscillator is very nearly a pure sine-wave tone.

3.4 The effect of other signals mixed with the injected tone

In addition to the modulation, which gives sideband frequencies lying quite close to the carrier, there will be, in general, signals from unwanted stations mixed with the injected tone. These are more widely separated in frequency from the wanted carrier, and are very greatly discriminated against in the synchronised oscillator, which acts as a very highly-selective tuned circuit (owing to its tuned regeneration). In addition to this frequency-discrimination, there is also some non-linear discrimination against these unwanted signals. Thus the output of the oscillator is substantially free of all interfering signals, and therefore only the wanted signals can be demodulated to audio-frequency in the receiver.

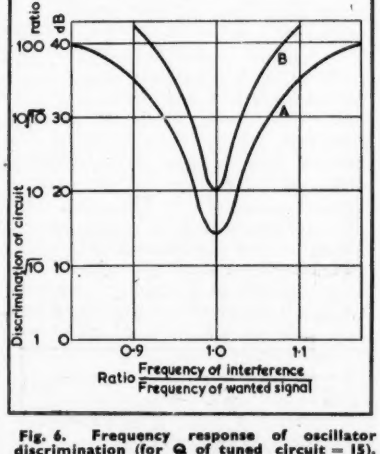


Fig. 6. Frequency response of oscillator discrimination (for Q of tuned circuit = 15). Curve A—injected synchronising signal of 0.1 volt. Curve B—injected synchronising signal of 0.03 volt.
(Note that discrimination is still obtained when interfering and wanted signals are of almost identical frequency.)

The magnitude of the selective effect of the synchronised oscillator can be judged from the typical example shown in Fig. 6, which shows the discrimination (of the same oscillator as before, with a Q-value of 15 for the tuned circuit) against frequency for two different voltages of the injected tone. The discrimination is different for different injected voltages because of the non-linear effect.

These discrimination values apply only so long as the unwanted signal does not exceed a certain amplitude relative to the wanted signal. As the unwanted frequency departs from the wanted frequency, so a greater amplitude can be tolerated. If it lies near the wanted frequency, it should not be of higher amplitude than the wanted signal. The synchrodyne (like most other circuits) cannot select a weak station closely adjacent to a very strong one unless a very high-Q tuned circuit is used in the oscillator, and the damping effect of the demodulator made negligible (by the use of a buffer amplifier stage if necessary. The selectivity of the oscillator circuit has, however, no effect on the frequency response of the main signal path.

3.5 The practical compromise

We have seen that the larger the injected voltage, the larger is the range of variation of natural frequency permissible in the oscillator. On the other hand, if the injected voltage is large, the discrimination against unwanted signals is small. Thus a compromise is necessary in practice.

It may be taken as a basis for trial that a typical oscillator circuit as

shown in the preliminary article will not vary in frequency more than about ± 0.1 per cent. in practice. The Q of the tuned circuit (allowing for the damping effect of the modulator) may be, say, about 50. If the valve is a H.F. pentode, say an SP41, a suitable peak amplitude of oscillation is about 1 volt, so that, from Equation (7), the value of the injected voltage needed to maintain synchronism is about 0.1 volt peak. This can be seen to give a moderate amount of discrimination in the oscillator, and is probably more than adequate for ordinary use. If especially high selectivity is required in the receiver, the injected voltage can be reduced considerably; synchronism can probably still be maintained without readjustment for hours at a time.

4. Linear demodulator circuits

It should be clear by now that the discrimination of the receiver is mainly obtained by means of the oscillator circuit, and not by means of any selectivity in the main signal transmission path. Thus all incoming signals are received in all parts of the main circuit, and to avoid unintentional demodulation (or " detection ") of unwanted signals by rectification, it is essential that all parts of the main circuit should be linear.* All non-linearity of the receiver is concentrated in the oscillator section.

The R.F. amplifier stages (if any) can be made linear enough by the use of negative feedback as necessary. The main problem is to make the demodulator sufficiently linear.

4.1 Valve-type demodulator circuits

A normal superheterodyne receiver uses a valve of some kind as a first demodulator (or " mixer," or " frequency-changer "), and the most common type of valve for this purpose is the triode-hexode. This includes the oscillator valve in the same envelope as the mixer. Such demodulating circuits are fully discussed in many published articles and books from among which we may usefully quote a paper by Herold[1] and a book by Sturley.[2]

It is difficult to obtain linear response from these valve circuits, especially in their simple form; the main requirement for linearity is a large demodulating voltage from the oscillator and a very low signal voltage. Since, however, a large oscillator voltage (which means the oscillator grid voltage in a triode-hexode valve) necessitates a large synchronising voltage, a good deal of preliminary R.F. amplification may be necessary to obtain a suitable voltage for synchronisation; this must then be attenuated in a pad of some sort in the main signal path before being applied to the signal grid of the hexode.

In a typical triode-hexode, a suitable oscillator-grid voltage may be about 10 volts peak, which will require a synchronising voltage of the order of 0.5 to 1.0 volt. This, as a signal voltage, is rather high for linear amplification, especially when we consider the presence of unwanted signals of larger amplitude. In actual practice tolerable results can be obtained with this voltage, but the use of a pad or potentiometer in the signal grid circuit is advised.

4.2 Ring-type demodulator circuits

For really good results the use of a ring-type demodulator circuit is advised. This uses four rectifiers arranged in a ring between transformers, as shown in Fig. 7(a), with the oscillator voltage fed to the centre-points of the transformer windings. The oscillator voltage should be large enough to switch the rectifiers from full backward resistance on one half-cycle to full forward resistance on the other, and vice versa. Then, ideally, the input signal would be reversed in polarity every half-cycle of the oscillator voltage without any change in its amplitude. (In practice, there is a change of amplitude, and it is not constant over the oscillator cycle.) The input signal is virtually multiplied by a square-wave function with a fundamental frequency equal to that generated by the oscillator. It is easily seen that this is the same as the process described in Section 2, except that we have not only the fundamental component of the oscillator frequency sin $(\omega_c t + \theta)$, but also the odd-order harmonics, sin $(3\omega_c t + 3\theta)$, etc., resulting from the square wave. It is also clear that the oscillator voltage has no effect providing it is large enough to switch the rectifiers. Such a circuit gives a good performance in the Synchrodyne receiver, because the switching voltage can be provided if necessary by the oscillator *output* (as compared with the grid voltage in the triode-hexode), and, in any case, for normal rectifiers such as crystal rectifiers of silicon or germanium types, or for small diodes such as type D1, the switching voltage need not exceed about 1.0 volt. The synchronising signal is proportioned to the grid voltage, and it need not exceed about 0.1 volt if, as discussed in Section 3.5, a H.F. pentode is used for the oscillator. This is quite a suitable input voltage for the demodulator, giving nearly-linear operation, so that the circuit design is perfectly straightforward and free from critical adjustments of level.

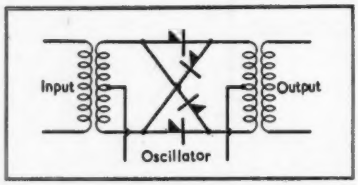


Fig. 7 (a). Ring demodulator circuit using two transformers.

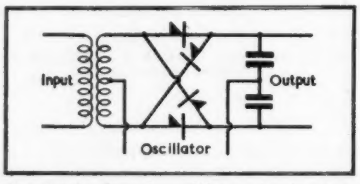


Fig. 7 (b). Ring demodulator circuit using a condenser feed for oscillator on output side.

Since, in the present application, the wanted product of demodulation is of very low frequency compared with the oscillator frequency, the output transformer of the circuit of Fig. 7(a) may be dispensed with, and replaced by two condensers as in Fig. 7(b). These are so chosen that they present only a low impedance to the oscillator frequency, but a high impedance to the audio-output.

It is important that the type of rectifier used should be suitable for use at frequencies around 1 Mc/s. Diode valves, such as the type D1, are perfectly satisfactory, but add the complication of a heater voltage supply. Crystal rectifiers of the modern type, using silicon or germanium crystals in robust capsules—often known as " crystal valves " or " crystal diodes "—are also very satisfactory so long as their circuit is earthed at some point; they

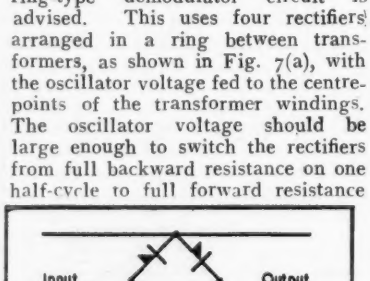


Fig. 8. Cowan demodulator circuit.

* By linear is meant that the output amplitude of any part of the circuit is strictly proportional to the input amplitude.

are manufactured by the B.T.H. and G.E.C. companies. Copper - oxide rectifiers, such as the Westector, have too large a capacitance to be really suitable; they give inefficient operation.

4.3 Cowan-type demodulator circuits

To avoid the use of a transformer altogether, the so-called Cowan-type circuit may be adopted. This is shown in Fig. 8, and was used in the receiver circuit shown in the preliminary article. The general method of operation is similar to that of the ring circuit in that the rectifiers are switched from high to high impedance by the oscillator, but this time the transmission path is almost short-circuited on alternate half-cycles of oscillator frequency, instead of being reversed in polarity. The results obtained are just the same, except for reduced efficiency and that some of the input signal appears unchanged in the output—but this is of no consequence. The switching voltage supplied by the oscillator must be double that used in the ring circuit, since it is developed across two rectifiers in series.

4.4 Demodulation of unwanted signals due to the odd harmonics in the multiplying function

It was pointed out earlier that owing to the square-wave nature of the switching action, the input signal was multiplied not only by the fundamental of the oscillator frequency, but also by its odd harmonics. As far as the wanted input signal is concerned, this does not matter, for the extra products of demodulation are of high frequency and disappear in the output circuit. However, if any signals of three times (or five times, etc.) the oscillator frequency are present in the input, they can be demodulated to audio by these harmonic components of the switching action (which have nothing to do with harmonics generated in the oscillator). This is not serious in practice, for the chance of any unwanted signal being an exact odd harmonic of the wanted signal is extremely remote. It is useful to be aware of the effect, however, since it accounts for stray whistles in unexpected places when the tuning condenser is turned through its range.

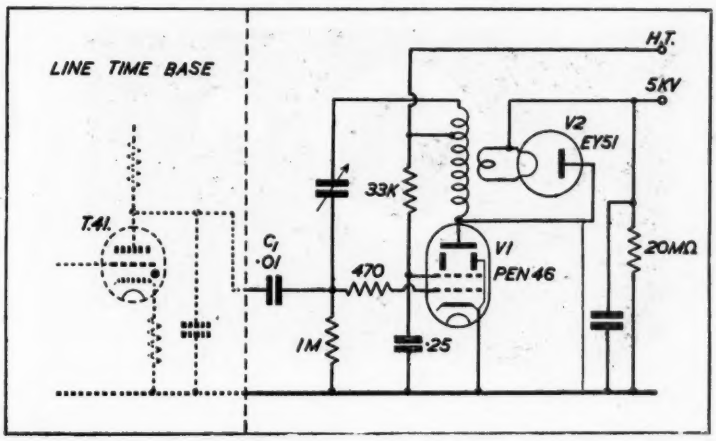
References

[1] Herold, E. W. "The Operation of Frequency Converters and Mixers for Superheterodyne Reception," *Proc. I.R.E.*, 1942, Vol. 30, p. 84.

[2] Sturley, K. R. "Radio Receiver Design," Vol. 1, p. 179, London, Chapman and Hall, 1943.

E.H.T. Supply for Television Receivers

By C. H. BANTHORPE*



SHORTLY after the end of the war the author made some experiments with the object of obtaining 5 KV in a cheap and simple manner. The experiments were successful and were on lines which had been well exploited during the war. More recently, however, a certain amount of cleaning up has been carried out, and it is thought that a short description would be useful to workers in similar fields.

The circuit is shown in the figure, and consists of a valve in the anode of which there is a tapped coil coupled to a much smaller coil.

The valve is switched on by the application into the grid circuit of a sawtooth waveform from the line time base, and current builds up in the anode circuit until the end of the line scan. The valve is then rapidly turned off, and the anode circuit "rings" at a frequency dependent upon the inductance of coil, and the capacity across it. This large oscillatory voltage at the anode of the valve is then rectified by a suitable rectifier and smoothed.

As the valve draws grid current at the tip of the sawtooth waveform the capacitor C_1 receives a charge which provides bias for the valve, and ensures a rapid and complete cut-off.

The H.V. rectifier, a Mullard EY51, has a particularly low wattage heater (approximately 0.5 W), and power for the heater is best supplied by a small coil, coupled magnetically to the "ringing" coil.

Some trouble was experienced by the high alternating voltage being fed back into the line time base via the anode/grid capacity of V_1 and causing a certain amount of distortion on the line scan, but a small degree of neutralisation completely cured that. Actually a 3-30 pF trimmer was used and adjusted until no modulation was visible on the C.R.T.

The coil consists of 3,000 turns of 42 s.w.g. enamelled and silk covered wire wound in three banks, on a 0.5 in. diameter former, each coil being 5/32 in. wide with a space of $\frac{1}{8}$ in. between coils The end coil has a tap at 150 turns from the start to provide the feedback potential as previously mentioned. A further 25 turns of 32 d.s.c. wire at a distance of 3/16 in. from the low potential end of the coil supply the power for the heater of the rectifier.

The coil former contains an iron dust core which is 1 in. long by 36 in. diameter. An Aladdin core No. PP.5750 has been found satisfactory. The coil has an inductance of approximately 120 mH.

This type of unit has been found to give very satisfactory results, and provides a cheap and convenient method of supplying the E.H.T. for a television receiver. The regulation is more than good enough for television purposes, and the device has none of the tuning problems of a continuously oscillating E.H.T. supply which seems to be coming into use in America.

* Central Equipment Ltd.

The author acknowledges the help of his colleague Mr. Hopengarten in the experimental work on this unit.

A Wide Range Audio Oscillator

By

F. W. DAWE,
A.C.G.I., M.I.E.E.*

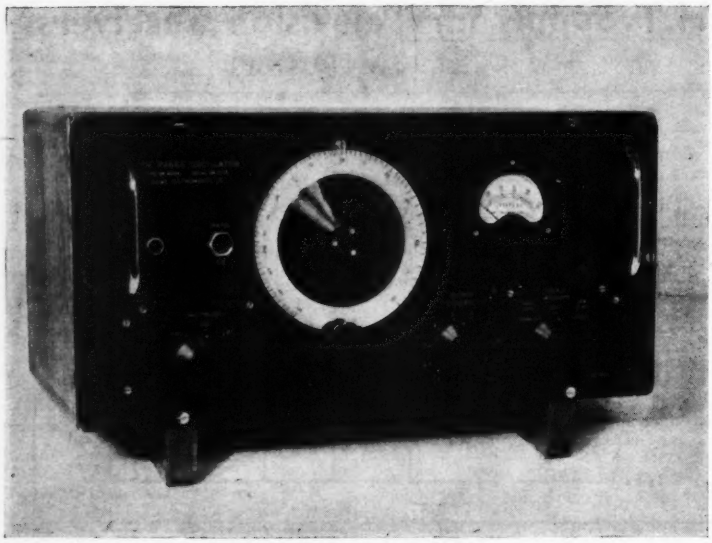


Fig. 3. Front view of audio oscillator.

FOR many years the terms "audio oscillator," "tone generator" and ones similar have been almost synonymous with "beat frequency oscillator." When any variable frequency audio source was required, a beat frequency instrument was invariably supplied. The practice can certainly be supported; the beat frequency oscillator is peculiarly suited for general purpose audio sources particularly in regard to the ease of achieving a wide frequency coverage on a single tuning control. It has, however, some serious shortcomings, among which are a lack of stability, a tendency to produce bad waveform, especially at low frequencies, and R.F. in the output. These disadvantages may be overcome by careful design and construction, but these, in their turn, produce an instrument of considerable size and cost. For reasonably priced, transportable equipment, other circuits are available and perhaps preferable.

With the conventional primary *L-C* oscillator not working in a beat circuit, it is difficult to secure a frequency coverage of more than 3 : 1, which means 6-7 bands are necessary to cover the usual audio spectrum of 20-20,000 c/s. The tuning capacitance, too, would have to be of prohibitive size for the lowest ranges and it would be very difficult to make the oscillator direct reading in frequency. However, with an *R-C* tuned circuit, a coverage of 10 : 1 can be easily achieved, reducing the bands to three, 20-200, 200-2,000 and 2,000-20,000 c/s. This type of circuit is nowadays consequently often adopted for audio oscillator work; it has other advantages also which will be later apparent.

* Dawe Instruments, Ltd.

The R-C Circuit

Of the several circuits possible perhaps the best is that of an amplifier back-coupled through some frequency discriminating network, such as a Wien bridge. This is shown schematically in Fig. 1. Resistors R_1-R_4 and condensers C_1-C_2 make up the bridge with the input and output of the amplifier connected to the diagonal points. By this means, both positive and negative feedback is applied to the amplifier. The positive feedback—through R_1C_1 and R_2C_2—causes it to oscillate at a frequency determined by

$$f = \frac{1}{2\pi\sqrt{C_1C_2R_1R_2}}$$

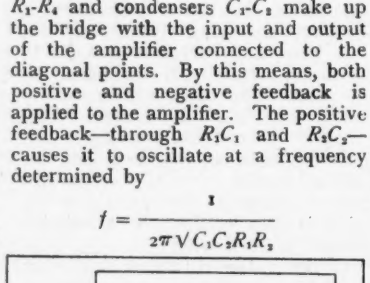


Fig. 1. Schematic diagram of Wein bridge back-coupled amplifier.

(assuming there is no phase shift in the amplifier) and the negative feedback—through the attenuating network R_3R_4 stabilises the level of the oscillation. The circuit has advantages over other R-C circuits in that for a given amplifier gain more negative feedback may be applied, as there is little attenuation in the positive feedback loop; and the input and output impedances of the amplifier are not directly connected across the arms of the frequency discriminating network (R_1C_1 and R_2C_2). Changes in amplifier characteristics do not therefore alter the oscillator frequency.

In order to keep the oscillation amplitude constant with change of frequency, the attenuation through the positive feedback loop must be maintained constant, *i.e.*, the ratio C_1/C_2 and R_1/R_2 must be constant. Adjustment of the frequency of oscillation can thus be made by variation of the values of either pair of components and is usually done by altering the capacitances C_1 and C_2 for continuous frequency variation and the resistances R_1 and R_2 in fixed steps to obtain a multiplier effect. By making one of the resistors of the negative feedback loop, say, R_4, a non-linear element which varies its resistance according to the current flowing, a high degree of amplitude stabilisation can be obtained. For example, in the circuit of Fig. 1, if R_4 is made a small metal filament lamp, when the amplitude of oscillation drops the current through the lamp drops, its resistance

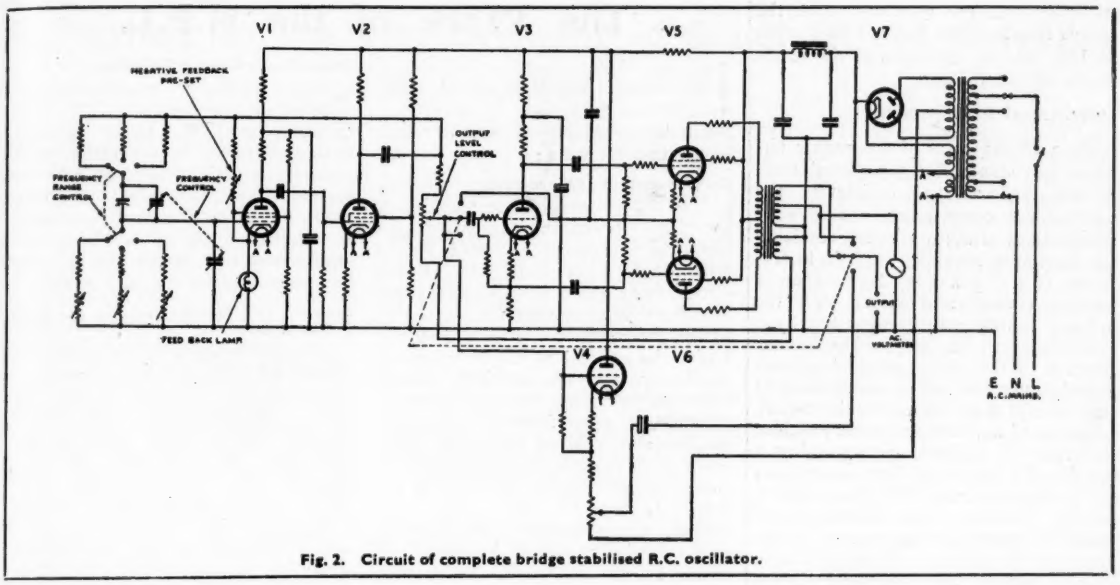


Fig. 2. Circuit of complete bridge stabilised R.C. oscillator.

decreases reducing the negative feedback and increasing the gain of the amplifier which compensates for the original drop in amplitude. By a suitable choice of values, a satisfactory compensation may be obtained.

Circuit of a Practical Instrument.

A circuit incorporating this bridge-stabilised R-C circuit is shown in Fig. 2. It will be recognised that the valve network V_1 and V_2 are substantially the same as Fig. 1, with the addition of range change switching, a trimmer condenser to improve tracking, and the 5W 230V lamp in the cathode circuit (R_4 of Fig. 1). The two tuning condensers are each formed of two sections in parallel of a standard 4-gang 0.0005 μF condenser, the ratios C_1/C_2 and R_1/R_2 being maintained at 1/1 on each range By the use of low temperature coefficient components in the bridge circuit, thermal drift is kept at a minimum. Because of this, and also because the drift is not magnified as with a beat frequency circuit, no zero setting device is necessary.

The oscillator section is followed by a triode "concertina" phase splitter which feeds a pair of output tetrodes in push-pull. Negative feedback in the amplifier, evening up the frequency characteristic, is supplied from a small tertiary winding on the output transformer; and throughout, the omission of cathode bypass condensers aids this effect. A level characteristic of ± 0.5db. is a representative figure for this class of circuit. The output transformer is tapped to provide a choice of impedances selected by a switch. 1 Watt is available at impedances of 500Ω and 2,000Ω, a voltmeter of the metal-rectifier type reading up to 100 volts on the high, and up to 50 volts on the low impedance position being connected. A supplementary low-level output position is provided by the valve V_4 which on the "low level" position is connected as a cathode follower and gives 1 volt maximum on open circuit or 0.5 volt into a 600 Ω load. This output has exceptionally low distortion—less than 0.5 per cent.—at all frequencies.

The power supply arrangements are conventional, consisting of the usual tapped-primary transformer and full-wave rectifier; but the smoothing

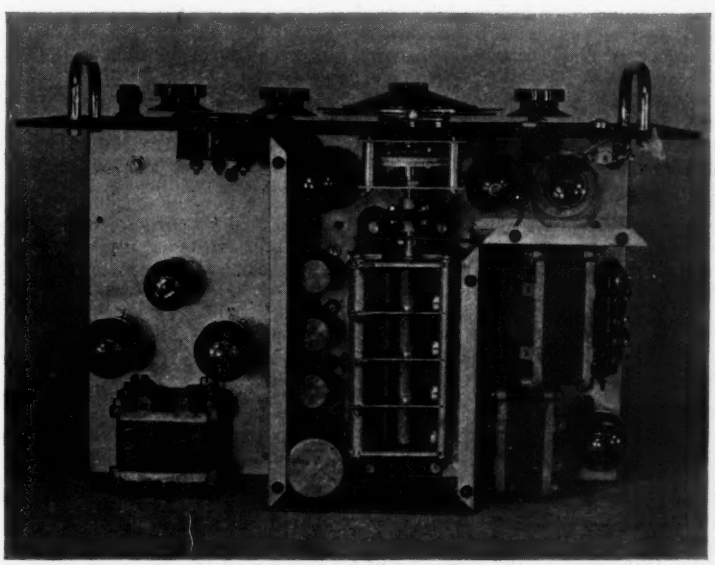


Fig. 4. Interior of oscillator viewed from above.

arrangements are generous, with the result that the hum level of the output is less than 0.2 per cent. of the maximum signal voltage.

Mechanical Arrangements

As a consequence of the simple circuits and standard conventional components of a R-C oscillator, the mechanical construction can also be simple and straightforward, resulting in maximum reliability. The instrument (Figs. 3 and 4) is built on a simple chassis and panel with the 4-gang tuning control operated by a 2 to 1 gear mechanism, so that the calibration of the lowest range is spread evenly over the full circumference of the control dial. A multiplier switch in steps of x1, x10, and x100 provides for the two higher ranges, giving a total scale length of between 36 and 48 inches. A continuously variable output control and a 3-position output selector govern voltage and impedance, while a meter, output terminals, mains switch and indicator lamp, complete the panel items. The whole unit is contained in a screened, polished hardwood case which is provided with sloping feet to bring the tuning dial, meter and control knobs, to a covenient height and angle for viewing, and easy operation.

Modifications and Specification

The standard instrument covers a range of 20-20,000 c/s. in three decades with a maximum output of 1W, but two modified models have also been made. One has an extra decade extending the coverage of 200 Kc/s., but due to the difficulty of constructing a transformer coupled amplifier of level response over the range 20 c/s.-200 Kc/s., the maximum output from the resistance coupled amplifier is limited to 100 mW into 1,000 Ω. The other, a special model of low frequency work, has a range of 0.1 to 1,000 c/s. in four decades, again with a maximum output of 100 mW.

The overall performance of all these instruments is more than adequate for ordinary testing, the low hum and distortion figure making them especially acceptable. The oscillator circuit is inherently stable both as regards frequency and output and due to the inclusion of the lamp stabiliser a further degree of stability is obtained. A disadvantage, compared with the beat oscillator, is perhaps the relatively restricted tuning without range switching, but it is thought this is more than offset by the other advantages of the R-C instrument.

The Work of the N.P.L.

In June visitors were invited to see the work of the National Physical Laboratory during a three-day exhibition. Among items of electronic interest were:

Cathode Ray Tube Chronograph

This chronograph was developed for high precision comparison in permanent form of standard clocks with each other and with Royal Observatory radio time signals. An electron beam sweeps vertically across the screen 100 times per second under the control of a quartz crystal oscillator, and the resulting traces are photographed on horizontally moving 35 mm. film. Fixed time marks, also derived from the oscillator and occuring at intervals of .001 secs., are superimposed upon the traces to form a time scale. The Royal Observatory time signals, radiated daily on a frequency of 16 Kc/s from the Rugby transmitter, and the time signals from the Laboratory standard clocks are recorded on the traces, and can be compared with an accuracy within one ten-thousandth of a second.

Electron Microscope

The electron microscope has been used in the examination of a number of metallurgical specimens including alloy steels and aluminium alloys.

All such work has been carried out with 'replica' techniques by which a 'replica' of the prepared metal surface is examined in the microscope instead of the original metal specimen on account of the difficulties inherent in the direct examination of metals in such instruments.

It is of prime importance to establish that results obtained by such indirect techniques really show the true nature of the metal surface and for this purpose comparisons have been made of results obtained from particular specimens using different replica techniques. The results, from a limited number of specimens only, encourage a preference for one particular type of technique.

The same experiments have shown that the advantages gained from electron microscopical work on this limited range of specimens as compared with optical work are connected not so much with the increased resolving power available as with a better appreciation of the surface geometry of the specimen which the method permits.

Geiger-Muller Counter Technique

The Laboratory has encouraged commercial enterprise in the production of G.M. tubes specially designed for X-ray diffraction work, and as a result of this co-operation an argon-alcohol filled tube is now being made commercially in this country. In addition a Geiger-Müller counter equipment of foreign manufacture has been acquired during the year.

Field-Strength Measurements at Centimetre Wavelengths

In order to study quantitatively the propagation of centimetre waves it has been necessary to develop, for such wavelengths, field-strength meters and standard radiators suitable for the calibration of transmitters and receivers The equipment shown was designed for operation at wavelengths of about 10 cm. and 3 cm. and consists essentially of antennae of known gain (determined experimentally) relative to a half-wavelength dipole. When radiating a known power such an antenna provides means for establishing a standard field, and when the antenna is used as a receiver and associated with a bolometer and suitable bridge circuit a field-strength meter is obtained. A modified form of Wheatstone bridge, which may be calibrated to give direct readings of radio-frequency power absorbed in a bolometer, has been designed for use with the equipment.

Dielectric Properties of Water at Centimetre Wavelengths

It is known that the propagation of centimetre waves is very much affected by atmospheric conditions, and a knowledge of the dielectric properties of the atmosphere and its constituents, particularly water and water vapour, is therefore needed for a full understanding of propagation processes. Such measurements can conveniently be made in a laboratory. For example, the reflexion and transmission coefficients of water, from which its dielectric constant can be deduced, have been measured in the Radio Division at wavelengths down to as short as 9 mm., by using miniature horn-type directional transmitters and receivers provided with means for giving a numerical measure of the received field intensities, the waves being reflected from or transmitted through very thin plane sheets of water.

A Method for the Measurement of Small Direct Currents

By E. J. HARRIS, Ph.D.*

RECENTLY a direct current amplifier has been described[1] which employs a commutator to convert the direct current into an alternating current to permit of amplification by A.C. coupled circuits. It may be of interest to describe an alternative system which was used in Germany to amplify the output from thermo-couples and low resistance photo-voltaic cells. It makes use of the fact that potential energy can be stored up in an inductance over a period of time, and then used to set up a ring, or damped oscillation, in a tuned circuit. The initial amplitude of the ring may be many times the E.M.F. applied to the primary coil because the ring can be set up in a secondary coil of high inductance. The direct current is fed via an interrupter through the primary coil, and the successive rings which appear across the secondary can be amplified by an A.C. amplifier. Fig. 1 shows the waveforms of the primary current and the secondary E.M.F. It is convenient to actuate the interrupter from the mains, in which case the interruption takes place at 50 c/s., and most designs of interrupter give approximately equal "on" and "off" periods. The natural frequency of the secondary circuit is made about 2 Kc/s.

After amplification the output can be rectified, but the direct current obtained in this way is not a linear function of the input current. A better method is to take some easily measurable E.M.F. and divide it down in a known ratio and finally feed it back into the input of the apparatus in opposition to the unknown E.M.F. The instrument is then used as a null indicator and the known current is adjusted until the ring waveform is a minimum. It has proved very convenient for making spectroscopic measurements in conjunction with a thermo-couple.

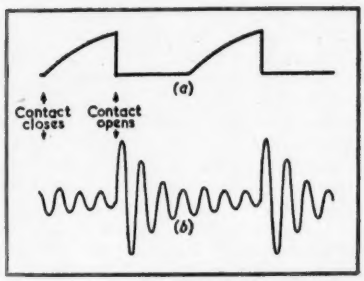


Fig. 1. (a) Primary current (b) secondary e.m.f. The 'ring' when the contact closes is due to contact e.m.f. and the residual energy in the circuit. Only the ring set up when the contact opens is of significance.

The signal to noise ratio attainable depends on the band-width of the amplifier following the input circuit. The German amplifiers had a pass band of several kilocycles, but it is considerably better to work with a band width of a few hundred cycles centred on the frequency of maximum intensity of the spectrum of the repeated ring waveform. Fig. 2 shows the form of the spectral distribution, and it appears that the best frequency band is centred at 0.8-0.9 of the natural ring frequency. There is nothing to be gained by reducing the band width below a few hundred cycles because the closing of the contact sets up some spurious ring, and this would interfere with the ring from the unknown current if the time constant of the amplifier were made greater than, say, 0.005 second. The sensitivity of the German instruments for signal equal to noise was found to be 0.1 microvolt from a 10 ohm source, but the noise did not originate in the source, as was found by shorting the input.

The design of the German apparatus was not complete, and the models which were brought to this country had a number of defects. It is therefore only possible to give an outline of the considerations which lead to best performance.

Fig. 3 shows schematically the input circuit. It consists of the "transformer" T, a resistance network to provide a small, calculable E.M.F. in the primary circuit to balance against the unknown, and the interrupter. The German transformers were wound on ordinary laminations, and had a turns ratio of 1 : 250 when operating from a 20-ohm source. The primary resistance was 42 ohms, and the Q of the secondary was about 0.5. These transformers were very prone to magnetic pick-up and it was found that improved performance was obtained by the use of toroidal coils wound on mu-metal strip cores. In this way the magnetic circuit was made more nearly perfect, and in addition the Q of the secondary was increased to 5. The amplitude ($\hat{V}$) of the first half-cycle of the ring is related to the circuit constants and the applied E.M.F. E, by the equation:

$$\hat{V} = E\sqrt{\frac{TR}{C}} \cdot \frac{1}{R+R_1} \cdot \left(1 - \varepsilon^{-\frac{T_1}{T}\left(1+\frac{R_1}{R}\right)}\right) \varepsilon^{-\frac{R\tau}{L}}$$

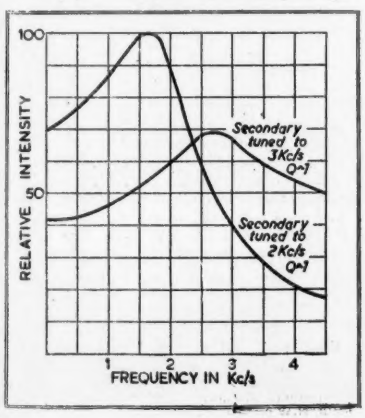


Fig. 2. Spectral distribution of energy equivalent to the repeated 'ring' wave form of Fig. 1 (b). Recurrance 50c/s.

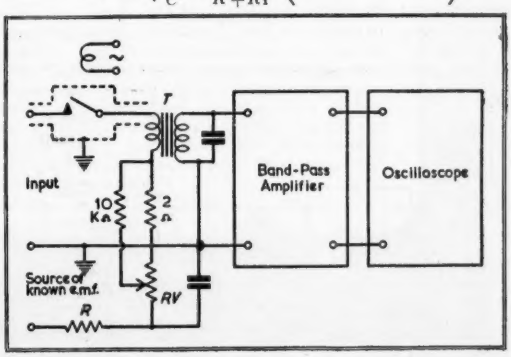


Fig. 3. (right) Input circuit.

* Biophysics Research Unit, University College.

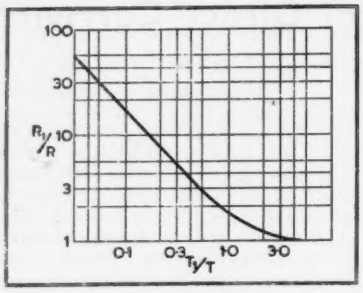


Fig. 4. Relation between $\frac{R_1}{R}$ and $\frac{T_1}{T}$ for optimum performance.

in which R_1 is the source resistance, R the primary resistance, C is the effective capacity across the primary, L the primary inductance, τ is the time between the contact opening, and $\hat{V}$ reaching its maximum, T_1 is the time during which the contact remains closed (usually 0.01 sec.) and $T = L/R$. Fig. 4 shows a plot of R_1/R against T_1/T for optimum $\hat{V}$. For example, with L equal to 0.1 H, R equal to 10 ohms, and T 0.01 sec., the constants suit a source resistance of 20 ohms. The amplitude of $\hat{V}$ is only reduced by 10 per cent. if R is twice or a half of the optimal value. The turns ratio should be the highest attainable consistent with the secondary becoming self-resonant at the ring frequency. Thorough magnetic screening of the input coil is essential. A double mu-metal box was used, and the inter-space was filled with pitch in order to preclude mechanical vibration.

A diagram of the interrupter is shown in Fig. 5. The soft iron armature (A) is supported on a phosphor bronze spring (S) between the poles of an alternating current electromagnet. The armature is polarised by a direct current field applied by the centre pole, and consequently it vibrates at the same frequency as the alternating current. The magnetic fields are applied through a thin aluminium diaphragm in order to reduce pick-up in the input circuit. The contacts of the vibrator are best made of material with a low contact E.M.F. with respect to copper (gold-silver alloy) and soldering should be carried out with the bismuth-tin alloy recommended in the reference. The whole interrupter is screened magnetically. In order to reduce loops in the wiring, which pick up stray magnetic fields, the interrupter and transformer are best mounted one over the other.

If the output is to be used only for null indication it is easy to arrange part of a sinusoidal time base, derived from the mains through a phase-shifting network, so that the first few half-cycles of the ring are spread across the screen. This increases the ease of the balancing operation.

It is possible to use the output waveform to control an apparatus. The sign of the first half-cycle of the ring is determined by the direction in which the primary current flows. By making a switch circuit sensitive to the polarity of the ring it becomes possible to operate relays or a motor. Thyratrons provide the most convenient sign sensitive circuit (*see* Fig. 6), the waveform is applied via a split secondary transformer to their grids, and in correct phase relation to the 50 c/s. A.C. applied to the anodes. The common cathode resistor R_0 ensures that only one valve fires, the other being held off. Each operation of the interrupter in the input circuit leads to the triggering of one of the two thyratrons. The anode loads R_1, R_2 are either relay coils for direct switching, or can be the coils of a reversible A.C. motor, in which case the direction of rotation depends on the sign of the off-balance at the input. If the motor is coupled to the potentiometer P a self-balancing system is obtained, which can be made recording by fitting a pen on the potentiometer shaft. The self-balancing principle can also be applied to a variable outside the apparatus itself. For example, if the input E.M.F. is produced by a thermocouple (Th) measuring an oven temperature the oven heating can be switched on or off according to the difference in E.M.F.s between Th and P. Additional to the function of ordinary thermostats, it is possible to make the reference E.M.F. from P vary in time by driving the potentiometer from a clock, so that the oven temperature can be controlled in time. This could be a valuable feature in a number of chemical and metallurgical processes.

[1] *Rev. Sci. Inst.*, 1946, 17, 194.

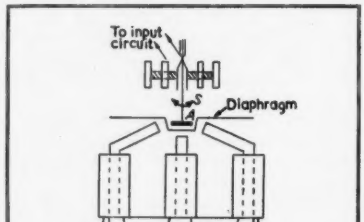


Fig. 5. (above) Diagram of interrupter.

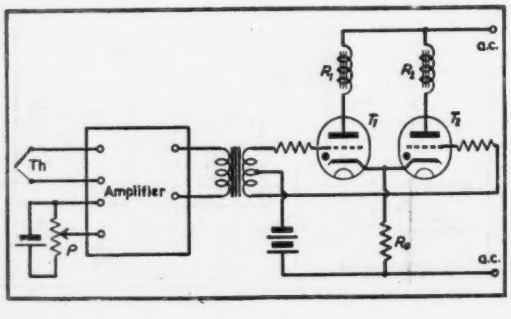


Fig. 6 (left). Arrangement to control oven by use of the off-balance between a thermocoupled (Th) and a motor driven source of reference potential (P).

Another Calculating Machine

In the isssue of December 1946 (p. 372) mention was made of the Automatic Electric Computer now under construction at the N.P.L.

A report appears in SCIENCE TODAY* of work started on a similar machine at the Princeton Institute of Advanced Study, under the direction of Dr. J. von Neumann.

The "memory" portion of the machine will be provided by special C.R. tubes known as "Selectrons," each of which will be able to store up more than 4,000 binary digits. The beam passes through a control mesh consisting of two sets of parallel wires, 65 wires in each direction, the potential of each wire being separately controlled. The screen on the far side of the mesh is thus divided into 4,096 squares, into which the beam can only penetrate if each of the four wires of the mesh through which is passes is suitably charged.

As successive pulses or "non-pulses" arrive for storage the control function is passed from one square of the mesh to the next, and the electrons are allowed to pass or held back accordingly. A succession of pulses separated in time is thus recorded as a succession of charges on the screen separated in space.

The apparatus should be more compact than the A.C.E. machine, which uses mercury tubes in its memory section.

* A weekly newsletter, published from 104 Clifton Hill, N.W.9. (No. 31, 15-5-47).

● The remarkable power factor and outstanding electrical insulating properties of "STYRAFOIL" brand Polystyrene have long been recognised by the electrical, radio and television industries. "STYRAFOIL" has a power factor of 0·0002-0·0004 which together with its negligible water absorption, has made possible the manufacture of equipment and apparatus not hitherto considered feasible. Its use in Radar equipment was a notable war-time achievement. Now "STYRAFOIL" is available for developments in expanding peace-time industry.

"STYRAFOIL" (Orientated Polystyrene Foil) is a plastic material endowed, as a result of molecular control during manufacture, with ten times the normal flexibility of ordinary Polystyrene film. It is supplied in spools of approximately 800 ft. lengths, from $\frac{3}{8}$" up to 13" in width, and in thicknesses from $\frac{1}{2}$/1000" to 6/000". Even in the thinnest dimensions this foil possesses a tensile strength of up to 10,000 lbs. to the square inch, and has the same superb electrical properties of Polystyrene mouldings and extrusions. A vast number of products and techniques awaits its use. Send for samples and further information.

BX PLASTICS LTD

Head Sales Office **HIGHAM STATION AVENUE · LONDON · E4**
Telephone LARKSWOOD 4491

AREA SALES OFFICES

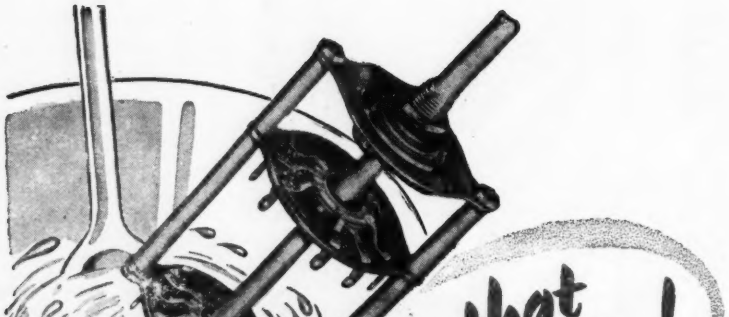
King Street Buildings
1 Ridgefield · Manchester 2
Manchester Blackfriars 0258

42 Wellington Street · Sheffield
Sheffield 25517

48 Moor Street · Birmingham 4
Midland 0132

Works **LONDON · MANNINGTREE · DUNDEE**

TAYLOR 1400



Break before make. This is an ideal Switch for use in any equipment where up to six circuits have been selected, and where the Switch must essentially be a non-shorting or break-before-make type, as for instance, where different voltages are selected on each circuit. On 2 wafers it provides 2 poles, giving 6 positions at 60° intervals. This double spacing ensures a definite break between a given position and those adjacent to it. Thus an operating circuit is completely broken before the next is selected.

WALTER INSTRUMENTS LTD., GARTH ROAD, LOWER MORDEN, SURREY. TELEPHONE: DERWENT 4421-2-3

WALTER Type 40

made for Life

1281

THE SWITCH OF OVER 2000 ASSEMBLIES

C.R.C.21

Radio Interference from Industrial R.F. Heating Equipment

By A. TURNEY, B.Sc.*

CONSIDERABLE information has been obtained relating to the reduction of interference from electric motors and the like in which radio frequency fields are produced as a by-product of the normal operation of the equipment and are essential to its proper function. This information has been embodied in various standards and codes of practice.† The increasing use of radio frequency power for industrial and medical purposes stresses the need for similar consideration of the class of equipments in which the production of large radio frequency fields is essential to their operation.

At present, little is known of the degree of interference caused, and no information is available regarding the nature of the stray fields from such equipment. However, some preliminary work has been carried out involving field strength surveys in the neighbourhood of R.F. heating equipment, measurement of R.F. voltage on the power supply mains, and in one case a determination of the effect of load heating on the operating frequency. The results of these measurements are described below, and it is hoped that they will serve to indicate the magnitude of the problem and give some idea of the effectiveness of the suppression already used. These tests have been, so far, of a limited character, but it is felt that the lower powered equipment, *i.e.*, up to about 5 KW, which has been given the most consideration, will be the largest potential source of interference. Such equipment is usually transportable, and any screening or other method of suppression must be integral with the equipment. Higher powered equipments are more likely to be erected on site and built into screened rooms which can be arranged to provide the degree of suppression required in the particular case.

The equipments tested were:

Manufacture A:

A.1. 45 KW induction heater, frequency 0.6 Mc/s.

Fig. 1. Field Strength of 45 KW in a screened equipment.

Circles have the source as centre and radial intervals of ½ mile.

A.2. Experimental 2.5 KW dielectric heater, frequency 15 M/cs.

Manufacture B:

B.1. 2.5 KW dielectric heater, frequencies 9.6 and 20.1 M/cs.

B.2. 2.5 KW dielectric heater, frequency 3.8 Mc/s.

Manufacture C:

C. 5 KW dielectric heater, frequency 18 Mc/s.

Manufacture D:

D. 1 KW dielectric heater, frequency 25 Mc/s.

Manufacture E:

E. 2-2.5 KW induction heater, frequency 16-18 Mc/s.

Facilities for these tests were obtained from the manufacturers of the equipment. The heater under test was operated inside the factory and the field survey made on and around the factory premises. In all cases the factories were situated in residential areas. The measurements were made with an interference voltage and field strength measuring receiver, which, for the field strength survey was operated in a light motor vehicle with the aerial, an 8 ft. vertical rod, projecting through the roof.

Source and Nature of Interference

Generators of radio frequency power for industrial and medical purposes employ, almost universally, thermionic valve generators, and in some cases, power amplifiers. Power is transferred from the generator to the load by a work circuit coupled to the oscillator or power amplifier tank circuit, both of which produce radio frequency fields which may affect radio receivers in the vicinity. Further, radio frequency currents may be injected into the power supply mains and cause interference by induction or re-radiation from the supply wiring.

The H.T. supply for the oscillator may be either unrectified A.C. or, as in the equipment tested, rectified single or three phase A.C. The amount of smoothing required is small and usually a single reservoir capacitor or choke input filter is used, hence it is reasonable to suppose that amplitude and frequency modulation of the oscillator will occur, due to the alternating component of anode voltage. Further, the operating frequency may vary due to changes of the electrical characteristics of the load during the heating period, so that interference may be caused over a band of frequencies about a mean value. Also, oscillator circuits of this nature generate harmonic frequencies and these will be radiated.

Measurements

A.1 (Induction heating installation, output 45KW at frequencies up to 0.6 Mc/s.):

The complete equipment was housed in a ½-in. mesh galvanised iron wire screen on the first floor of the building. A standard type of high-frequency filter was installed in the mains supply. The field strength survey (Fig. 1) was made with the equipment unloaded, but operating with a current of 150 amp. in the load coil. The measurements show that the field attenuates rapidly with distance within a radius of 200 to

TABLE I
HARMONIC LEVELS RELATIVE TO THE FUNDAMENTAL IN DB

Harmonic		2	3	4	5	6	7	8	9	10
Level, db	No load	−4.5	< −40	−16	< −40	−17.5	< −40	− 23	< −40	−24
	Loaded	−5.0	− 9	−18						

* The British Electrical and Allied Industries Research Association.

† e.g., B.S. 505, 613, 727, 800, 827, 833, 905, and B.S.I.-I.E.E. Codes of Practice on the Abatement of Radio Interference from H.F. Medical and Industrial Equipment and from Automobiles, etc.

TABLE II

	Nominal Power, KW	Frequency Mc	Remarks	Field Strength* Contour Area sq. miles						Mean Contour Radius, miles						Radiated Power mW	
				20 db	30 db	40 db	50 db	60 db	70 db	20 db	30 db	40 db	50 db	60 db	70 db		
A.1	45	0.6	Housed in screened room of ½ in mesh × 16 S.W.G. galv. iron netting. (Single screen.) Filtered supply.	—	.027	0.0045	—	—	—	—	0.093	0.038	—	—	—	—	A.1
A.2 (a)	2.5	15	Unscreened. Located in semi-basement with tank circuit at ground level.	—	2.4	0.52	0.11	0.039	0.013	—	0.87	0.41	0.19	**0.11**	0.065	240	A.2 (a)
A.2 (b)	2.5	15.8	As for A.2 (a) but load circuit removed.	—	1.9	0.48	0.16	0.047	0.012	—	0.78	0.39	0.23	**0.12**	0.062	340	A.2 (b)
B.1 (a)	2.5	9.6	Self-screened by sheet steel cabinet. Filtered supply.	0.10	—	—	—	—	—	**0.18**	—	—	—	—	—	0.17	B.1 (a)
B.1 (b)	2.5	20.1	As for B.1 (a)	0.15	—	—	—	—	—	**0.22**	—	—	—	—	—	0.39	B.1 (b)
B.2	2.5	3.8	As for B.1 (a) but unscreened electrodes.	—	1.2	0.41	—	—	—	—	0.62	**0.36**	—	—	—	280	B.2
C	5.0	18	As for B.1 (a) but extra screen enclosing oscillator only.	0.13	—	—	—	—	—	**0.20**	—	—	—	—	—	0.27	C
D	1.0	25	As for C	0.14	—	—	—	—	—	**0.21**	—	—	—	—	—	0.32	D
E	2.5	17.4	As for B.1 (a)	—	—	0.011	—	—	—	—	—	**0.059**	—	—	—	0.21	E

* Field Strengths in db above 1μV per metre.

300 yards of the equipment, indicating that induction fields predominate in this region. At greater distances, where the radiation field would predominate, the magnitude of the field is negligible. The slightly directional pattern of the field contours may be due to the orientation of the oscillator tank coil. Measurements at harmonic frequencies, summarised in Table 1, show that the even order harmonics have appreciable amplitude, while none of the odd orders were measurable. A load of about 5 KW in the form of a steel block caused a slight change of frequency and reduced the amplitude of the fundamental, but did not materially affect the relative amplitudes of the second and fourth harmonics. However, a third harmonic of appreciable magnitude was introduced.

A.2 (Experimental equipment for dielectric heating, output 2.5 KW at frequencies up to 15 Mc/s.):

No screening or filtering had been provided, and the equipment was operated in a semi-basement with the oscillator tank coil at approximately ground level. In order to determine the effect of the work electrodes, a parallel pair of flat plates 12 in. square and 3 in. apart, two surveys were made, Fig. 2, with the work circuit coupled and tuned, but not loaded, and Fig. 3 with the work circuit completely removed, but the oscillator operating as nearly as possible under the same conditions. For the first survey the frequency was 15 Mc/s. and for the second 15.8 Mc/s. These two surveys, together with the contour area measurements given in Table 2, show that, although the field patterns differ, the areas of corresponding contours are approximately the same, and that the field is due to both oscillator tank circuit and work electrodes, whose contributions are of similar magnitude. The relation between field contour areas and intensity levels would suggest that the field is due to radiation. Both amplitude and frequency modulation were observed on this equipment.

B.1 (Standard equipment for dielectric heating, output, 2.5 KW at frequencies between 5 and 20 Mc/s.):

Oscillator and power supply were housed in a sheet steel cabinet with the work electrodes housed in a small perforated steel cabinet at the side. A commercial type of filter was used in the mains input. Two field surveys were made, Fig. 4, at a frequency of 9.6 Mc/s. and Fig. 5 at 20.1 Mc/s. with the equipment

operated without a load on the ground floor of the maker's premises. In both surveys insufficient measurements were obtained for the purpose of plotting field contours, so the 20 db. contours shown were estimated on the assumtion of a field which varies inversely as the square of the distance from the source. This assumption was based on the results of the measurements on A.2 and B.2 which showed that the field strength varied according to this law at distances which were large compared with the wavelength of the source. Amplitude and frequency modulation effects were observed in both cases. With the equipment operating at 9.6 Mc/s., the second harmonic amplitude was found to be 3 db. below that of the fundamental at a range of approximately 20 yards.

B.2:

This equipment was similar to B.1, but modified for use with external electrodes in the form of a pair of parallel strips 3 in. wide and 5 ft. long, separated by approximately 1 in. These electrodes were remote from the generating equipment and were supplied by a low impedance co-axial cable with a tuned impedance matching circuit close to the electrodes. The oscillator and power supply screening and filtering were similar to those for B.1, the impedance matching circuit was screened by a metal cabinet, but the work electrodes were unscreened. The field survey, Fig. 6, was made at a frequency of 3.8 Mc/s. with a current of 17 amp. flowing into the work electrodes. The manner in which the field attenuates with distance from the source, i.e., approximately inversely as the square of the distance, suggests that the field is due to radiation. The fields produced by this equipment are greater than those due to the prototype B.1 because of the unscreened work electrodes. Measurements made at harmonic frequencies at a range of 0.25 mile showed that all harmonics up to the 6th were more than 30 db. below the fundamental amplitude. This low level of harmonic radiation is probably due to the additional filtering provided by the tuned matching circuit.

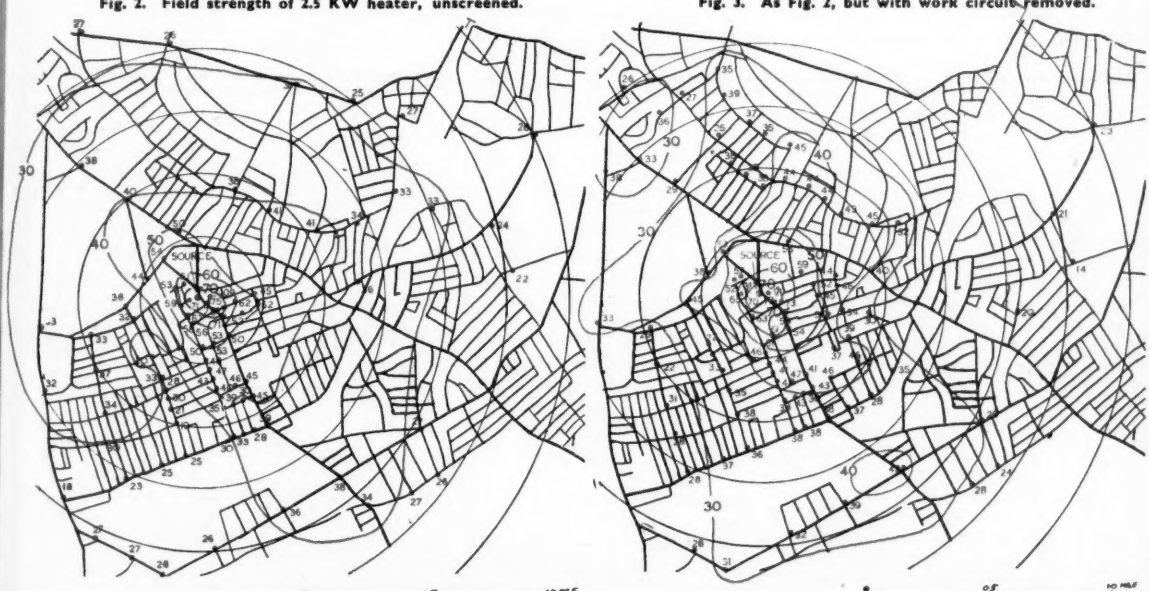
Fig. 4. Field strength of 2·5 KW standard equipment at 9·6 Mc/s. Sheet iron cabinet.

C (*5 KW output dielectric heater for preheating bakelite moulding powders*):

The full R.F. power was delivered by a single Colpitts type oscillator stage operating at a nominal frequency of 18 Mc/s., housed, together with anode supply rectifying equipment, in a sheet steel cabinet. The work electrodes were a pair of 15 in. square plates mounted horizontally in a sheet metal cabinet attached to the main equipment and coupled to the oscillator tank coil by a movable coupling coil. Variation of output power could be made both by varying this coupling and by adjustment of anode voltage. Anode voltage adjustment was made by alternative star and delta connection of the power transformer and by grid control of the mercury vapour rectifiers. Screening for the complete equipment was provided by the metal cabinet and by a separate internal screen of aluminium-sprayed perforated sheet iron enclosing the oscillator. There were two breaks in the inner screen, for the H.T. and L.T. supply and the connexions to the work electrodes. No special precautions were taken over

Fig. 2. Field strength of 2.5 KW heater, unscreened.

Fig. 3. As Fig. 2, but with work circuit removed.



Note: In these and the following charts the figures indicate *db* above 1 μV per metre.

the bonding of cabinet doors. A two-stage R.F. filter was provided in each phase of the power supply, the filter casing being mounted directly on the cabinet framework. Fuses were included in series with each filter capacitor to give protection in case of a failure. A field survey, Fig. 7, was made with the equipment located on the first floor of the factory building and operating without a load under conditions of maximum anode voltage and maximum coupling to work electrodes, *i.e.*, the most severe conditions likely to be met in practice. The R.F. voltages measured on the power supply were:—

Phase	*Voltage*
1	0.17
2	0.47
3	0.17

These voltages are sufficiently high to cause interference by direct coupling along the power supply wiring.

Measurements were made to determine oscillator frequency drift with load heating for cases of light and heavy loading. The light load comprised two 2 in. phenol resin wood flour-filled preforms and gave a loading of about 0.5 KW with a heating time of 1¼ minutes, and the heavy load seventy-two 1 in. by ½ in. preforms of similar material giving a load of about 4 KW with a heating time of 1¼ minutes. With the light load, the frequency varied within a band of width 0.05 Mc/s. about the mean frequency 16.4 Mc/s., while the heavy load caused the frequency to

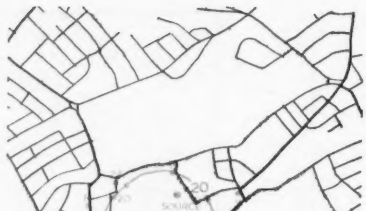


Fig. 5. Survey as in Fig. 4 but at 20.1 Mc/s.

vary between the extreme limits of 16.9 to 16.3 Mc/s., *i.e.*, within a band of total width 7.2 per cent. of the mean frequency. Should the mean frequency fall within or sufficiently close to a broadcast band, interference could take place with a number of channels during a single heating cycle, however, the duration of the interference with a given channel would be only a fraction of the heating cycle due to the frequency drift.

D (Dielectric heater for preheating bakelite moulding powders, output 1 KW at a nominal frequency of 25 Mc/s.):

The power was delivered by a single Hartley type oscillator housed together with the anode supply rectifying equipment in a sheet iron cabinet which was zinc-sprayed internally, with the zinc spray extending to the outside of the cabinet at the edges of the doors in order to provide a good contact between door and cabinet. The work electrodes, which were a pair of plates 7 in. by 7½ in., were housed in a compartment at the top of the cabinet and were connected directly to the oscillator tank circuit. Anode supply voltage was fixed and power output was adjusted by variation of air gap between the upper work electrode and load. Particular care had been taken over the bonding of this compartment, spring earthing clips being provided all round the edge of the cover. In addition to the screening provided by the outer case, an internal copper screen enclosed the oscillator, power supply leads being decoupled to the screen at the point of entry. A single-stage R.F. filter was connected in each power supply line, the components being mounted in a copper box fitted to the metal framework. Mains supplies were brought to the filter through a steel conduit bonded to filter and cabinet at the entry point. The field survey, Fig. 8, was made with the equipment operating inside a single story, steel-framed factory building; work electrodes were spaced by 1½ in. and no load was applied. Voltages of 450 μV and 320 μV were measured between supply lines and ground at the oscillator frequency of 25.1 Mc/s.

Fig. 6. Field from 2.5 KW 3.8 Mc/s heater with unscreened work electrodes. Sheet iron cabinet.

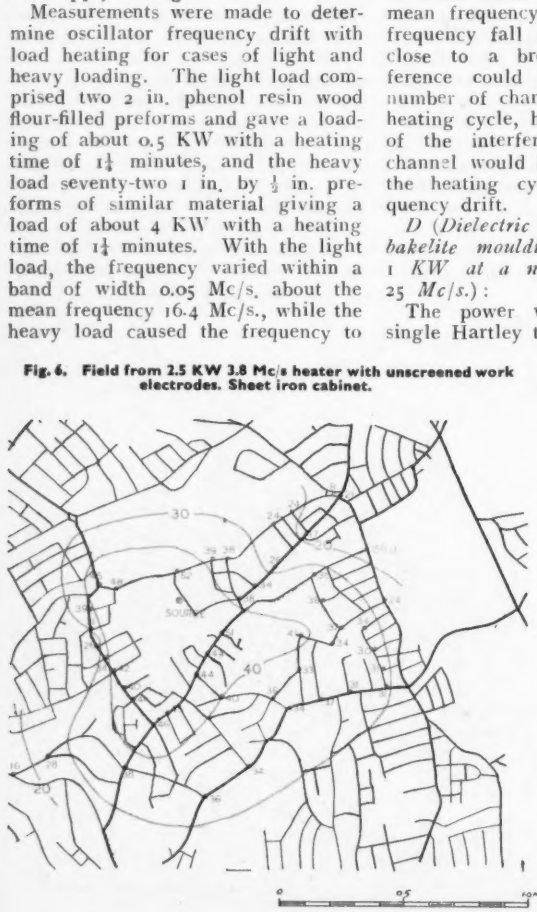
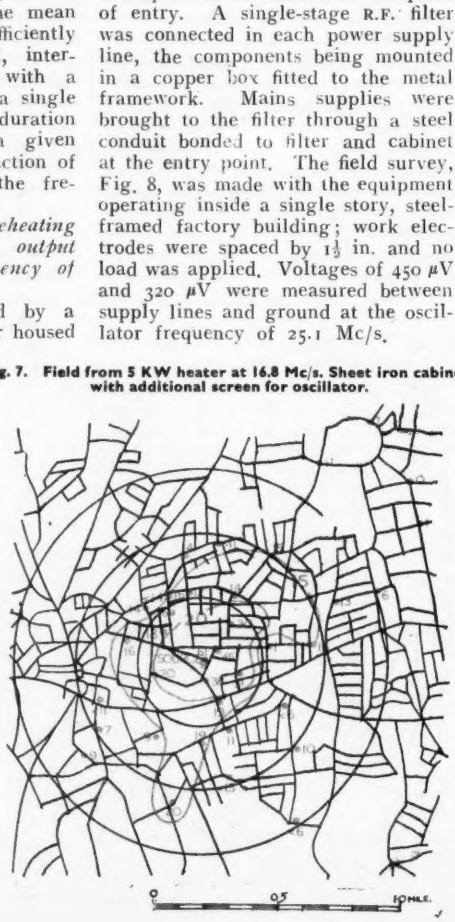


Fig. 7. Field from 5 KW heater at 16.8 Mc/s. Sheet iron cabinet with additional screen for oscillator.



E (*General-purpose* R.F. *heater output about 2 KW at a nominal frequency of 17 Mc/s.*):

The R.F. power was generated by a single oscillator stage having grid drive provided by a coil inductively coupled to the oscillator tank circuit. Power was taken from the oscillator by a variable self-inductance coupled with the oscillator tank circuit, load control being effected by variation of the work circuit reactance. This particular equipment was arranged for induction heating, a capacitance being included in series with the work coil to reduce the work circuit reactance sufficiently to obtain the required power output. Screening was provided by the sheet-iron cabinet and the power supply was filtered.

The measurements were confined to the field survey, Fig. 9, which was made with the equipment delivering about 0.5 KW into a steel cylinder placed in the work coil. It was considered that the building housing the equipment, which was steel framed and had a sheet-iron roof, and the surrounding buildings provided some additional screening.

Discussion

The earlier observations regarding modulation effects, harmonic radiation and the dependence of frequency on load temperature have been largely confirmed by the results of these measurements. Further, the results show that, at distances greater than the source wavelength, the field amplitude attenuates approximately inversely as the square of the distance from the source. Under the conditions of measurement, *i.e.*, fixed transmitter and receiver heights above the ground, this is consistent with the ground having a reflexion coefficient near to -1; the received voltage is then due to the direct ray and that from its image in the ground plane. If this assumption is made, the power in the vertically polarised field may be estimated by replacing the source with a short vertical radiator of length l carrying a uniform current I amp, r.m.s. The field due to the element and its image is given by

$$\xi \simeq \frac{240\pi^2 I l h_t h_r}{\lambda^2 r^2} \qquad \ldots\ldots\ldots\ldots (1)$$

if h_r/r and $2\pi h_t h_r/\lambda r$ are small angles. Where

ξ is field strength, volts per metre.

h_t and h_r are transmitter and receiver heights in metres.

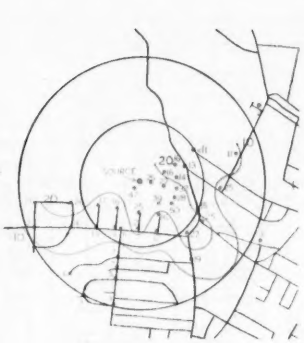


Fig. 8. 1 KW Heater at 25.1 Mc/s. Sheet iron cabinet.

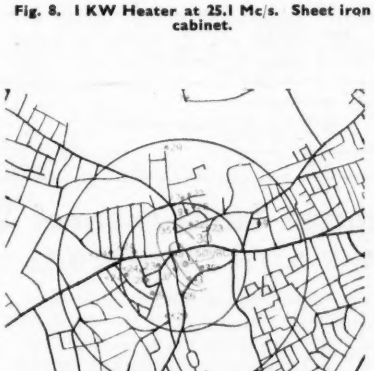


Fig. 9. 2.5 KW heater at 17.4 Mc/s. Sheet iron cabinet.

λ is the wavelength of the source, metres.

r is the distance between transmitter and receiver, metres.

The radiation resistance of the element in the presence of its image is

$$R = \frac{80\pi^2 l^2}{\lambda^2} + \frac{15 l^2}{h_t^2}\left\{\cos\left(\frac{4\pi h_t}{\lambda}\right) - \frac{\lambda}{4\pi h_t}\sin\left(\frac{4\pi h_t}{\lambda}\right)\right\}$$

where the first term is the radiation resistance of the element in free space and the second the mutual resistance due to the image. Writing the cosine and sine functions in series form gives

$$R = \frac{3840\pi^4 l^2 h_t^2}{\lambda^4}\left[\frac{4}{5!} - \frac{6}{7!}\left(\frac{4\pi h_t}{\lambda}\right)^2 + \frac{8}{9!}\left(\frac{4\pi h_t}{\lambda}\right)^4\right]$$

The series converges rapidly, and if

$$\frac{5!}{4} \times \frac{6}{7!}\left(\frac{4\pi h_t}{\lambda}\right)^2 \ll 1,$$

i.e.,

$$\frac{4\pi^2}{7}\,\frac{h_t^2}{\lambda^2} \ll 1$$

$$R \simeq 128\pi^4 l^2 h_t^2/\lambda^4$$

and the power radiated

$$W \simeq 128\pi^4 I^2 l^2 h_t^2/\lambda^4 \qquad \ldots\ldots\ldots\ldots (2)$$

Eliminating the moment of the element, Il, between (1) and (2).

$$W \simeq \epsilon^2 r^4/450 h_r^2$$

The mean height of the receiving aerial was 3 m. in all cases, so that

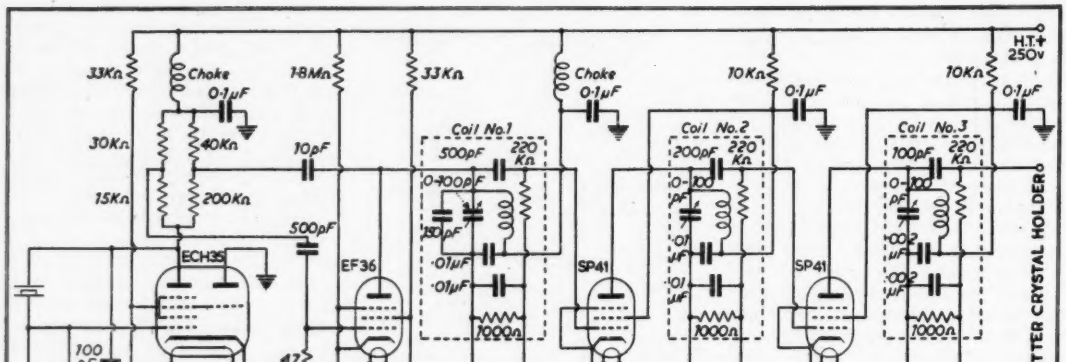
$$W \simeq \epsilon^2 r^4/4.05 \text{ mW}.$$

The radiated powers given in Table II have been calculated by this method from the heavy type in the same table. (No calculations were made for A1 as the measurements were made within the induction field region). Further measurements would be required to check the validity of these assumptions which, if true, would indicate that most of the radiation would be directed skyward and for apparatus radiating a watt or more might cause interference at great distances due to reflections from the ionosphere. Fully screened equipment radiating less than a milliwatt would cause interference only at short distances.

The powers radiated by the full-screened equipments are very small and it is doubtful if these would cause interference, except with a service having a low field strength in the neighbourhood of the heater. For these equipments, the radiated power is 60-70 db below the generated power. On the results of these measurements there seems to be little support for the use of an additional screen enclosing the oscillator, as the work electrodes or coils are one of the principal sources of radiation. Unscreened and partially screened equipments A.2 and B.2 radiated powers of the order of a watt and may be potential sources of interference at much greater distances due to reflected skywaves.

Closely connected with the screen-

(*Concluded on p.* 264)



A Frequency-modulated Multi-channel V.H.F. Radio Link

By E. S. TELTSCHER, B.Sc.

OPERATIONAL requirements often demand the establishment of a flexible multi-channel radio link, *i.e.*, a link on which several speech channels, teleprinter, or high-speed telegraphy channels can be transmitted simultaneously.

Such a link usually employs a multi-channel equipment such as a 1 + 4 carrier telephone equipment, which transmits audio-bands of approximately 2.6 Kc/s. bandwidth by modulating speech or tone frequencies on carriers spaced approximately 3 Kc/s. apart, and subsequently suppressing both the carrier and one sideband. In the 1 + 4 equipment, if group modulation is not used, the transmitted band of frequencies lies between approximately 300 c/s. and 15.7 Kc/s.[1] Several sidebands, corresponding to several channels are thus transmitted, and subsequently filtered and demodulated at the receiving end.

A very high degree of linearity in the radio link is, however, required to make such a system feasible, as any non-linearity in the radio-link reflects itself in undesirable cross-talk in the various channels, which can be of a sufficiently high level to render the system entirely useless.

It soon became apparent that existing amplitude modulated equipment, designed originally for single-channel communication, would have to be completely redesigned before the required degree of linearity could be obtained, and it was therefore decided to utilise a frequency modulated link, since one of the advantages of F.M. is the high degree of linearity obtainable by cutting out the modulator in the transmitter, where the bulk of the distortion usually arises.

An F.M. adaptor (the circuit diagram of which is shown in Fig. 1) containing four valves, was designed for a standard V.H.F. transmitter, which required no modification, as the output of the adaptor was fed into the crystal socket of the original amplitude modulated, crystal controlled transmitter. A standard V.H.F. receiver, capable of both A.M. and F.M. reception, was modified for crystal control for use in the initial experiments. Service requirements may demand the use of a fairly low deviation (approximately ± 30 Kc/s.) as well as simplicity of design and a crystal-controlled phase modulator circuit was therefore utilised, frequency modulation being obtained by the well-known method of inserting an L.F. resistance-condenser network in the audio-input side of the phase modulator, which progressively attenuates the higher audio-frequencies. From this, it is apparent that the largest phase angle deviation for a given input level will occur for the lowest audio-frequency, which we can assume to be 300 c/s. As the harmonic content of the phase modulator output diminishes very quickly as the phase angle is decreased, it is convenient to use the lowest frequency band (300-3,000 c/s.) as a speech channel. Thus, the harmonics of the lowest frequencies (from 300 c/s. upwards) will only appear in their own speech channel, whereas the harmonics of the higher speech frequencies (from 1,000 c/s. upwards) appearing in the next channels will be of small magnitude.

The phase modulator utilises two valves and operates on a similar principle, but is of simpler design than the original Armstrong phase modulator. Only odd harmonics are produced by a properly adjusted phase modulator.

Thus, assuming a permissible distortion of 1 per cent. third harmonic for 1,000 c/s.—higher frequencies will have a rapidly diminishing harmonic content—the phase deviation of the modulator is fixed at 0.2 radian.[2]

Fig. 1. (above) Circuit diagram of F.M. adaptor.

Then :

$\Delta F = 30$ Kc/s. $f = 1$ Kc/s.

$\frac{\Delta F}{f} = 30$ radians.

and the minimum multiplication factor necessary to achieve the required deviation at the transmitter output is therefore[3]

$$\frac{30}{0.2} = 150$$

Since the radio frequencies used are in the region of 65-95 Mc/s., and to allow for slight misadjustments, etc., a multiplication factor of 192 was actually chosen, which results in a band of crystal frequencies from 338-495 Kc/s.

As the transmitter already possesses a multiplication factor of 12—reckoned from the original transmitter crystal oscillator—it was only necessary to provide for a further multiplication factor of 16, by incorporating a quadrupler and doubler stage in the F.M. adaptor and utilising the original transmitter crystal oscillator stage as doubler. It will, of course, be appreciated that each radio frequency multiplication also multiplies the deviation by a corresponding amount.

The phase modulator used in this system consists of two valves (Fig. 1), *i.e.*, a crystal oscillator valve with its associated circuit, which is designed to give a level output of radio frequencies for crystals with varying activity, and the phase modulator proper. The latter consists of a pentode, with a tuned circuit as anode load. Two voltages are fed into this tuned circuit.

(1) The R.F. voltage fed on to the grid of the pentode and amplified within the valve.

(2) A R.F. voltage fed via the 10 pF capacitor directly into the tuned circuit.

Voltage (1) is grid modulated by audio-frequencies appearing across the L.F. R.C. network. The cathode resistor controls the magnitude of the grid modulated vector across the tuned circuit and also reduces any distortion present due to grid modulation. The reduction in distortion due to the cathode resistor is less than that of a class A feed-back amplifier.

The operation of the phase modulator can be explained as follows :

Consider the general case of a unit vector V_1 (representing the R.F. voltage fed into the load circuit via the 10 pF coupling capacitor) subtending an angle α with the vector V_a varying in amplitude (representing the grid modulated R.F. voltage fed into the load circuit via the valve). Let the resultant vector V_r subtend an angle θ with vector V_1, and let V_a be varied by an amount $\pm \delta V_a$ resulting in a corresponding variation of $\pm \delta\theta$ (Fig. 2).

Then :

$$\tan(+\delta\theta) = \frac{\delta V_a \sin(\alpha-\theta)}{V_r + \delta V_a \cos(\alpha-\theta)} \quad \text{(i)}$$

$$\tan(-\delta\theta) = \frac{\delta V_a \sin(\alpha-\theta)}{V_r - \delta V_a \cos(\alpha-\theta)} \quad \text{(ii)}$$

To avoid even harmonics $\cos(\alpha-\theta)$ must be zero, *i.e.*, $(\alpha-\theta) = \frac{1}{2}\pi$ and the resultant vector V_r must be at right angles to V_a. Hence :

$$V_r = \sin\alpha \quad \text{(iii)}$$

and from (i) $\tan\delta\theta = \dfrac{\delta V_a}{\sin\alpha}$

or :

$$\frac{\alpha\theta}{\alpha V_a} = \operatorname{cosec}\alpha \quad \text{(iv)}$$

From the expression (iv) it can be seen that the greatest rate of change of phase angle per given amplitude change of vector V_a occurs when vectors V_1 and V_a tend to subtend an angle of 180°. At the same time it can be seen from expression (iii) that the resultant vector V_r decreases progressively in magnitude, and a compromise has therefore to be adopted in practice between these two requirements, *i.e.*, minimum distortion achieved by a low degree of grid modulation but producing comparatively large phase angle deviations, and stablity, as too great a reduction of vector V_r leads to instability of the output. In practice an angle of approximately 150° is chosen.

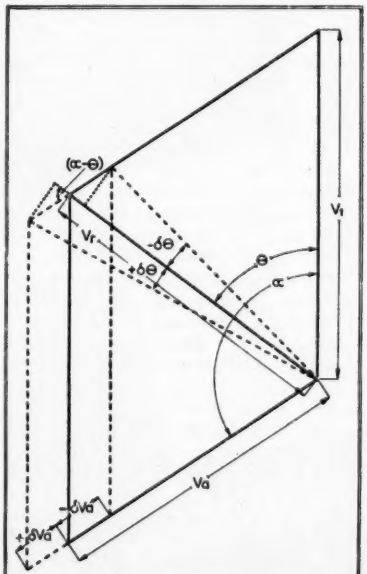


Fig. 2. Vector diagram of phase modulator.

By making $(\alpha-\theta) = \frac{1}{2}\pi$ no second harmonic distortion occurs in a properly adjusted phase modulator. Odd harmonic distortion—the third harmonic being prominent—results from phase angle deviations which are too large, as expression (iv) holds only for small angles. A 10° angle variation either side produces approximately 1 per cent. third harmonic distortion, as has already been stated. The resultant vector V_r varies not only in phase but also in magnitude. The latter variations are, however, taken up in the following stages, which act as limiters.

From expression (iv) it can be seen that for small angles the phase angle varies linearly with the amplitude of vector V_a which is the condition for true phase modulation. The resultant voltage vector can therefore be re-written as :

$V_r = V_r \sin(2\pi Ft + \Delta\theta \sin 2\pi ft)$

where F = Radio frequency

f = Audio frequency

$\Delta\theta$ = Maximum phase angle excursion.

It will be noted that the expression in brackets denotes the angle through which the rotating vector V_r moves in t seconds. Therefore the differential of this angle with respect to time must be the instantaneous angular velocity Ω_t

$$\therefore F_t = \frac{\Omega_t}{2\pi} = \frac{d}{dt}\left(\frac{2\pi F_t + \Delta\theta \sin 2\pi ft}{2\pi}\right)$$

$$\therefore F_t = F + f\Delta\theta \cos 2\pi ft \quad \text{(v)}$$

The instantaneous frequency deviation due to phase modulation is therefore directly proportional to the audio-frequency.

Insertion of an R.C. series network in the audio-input stage of the modulator will fulfil the required condition of a L.F. network, provided R is made large in comparison to $1/\omega C$, thus offering a fairly constant impedance to audio-currents. The audio-voltage across C will therefore be inversely proportional to the audio-

frequency. Thus true frequency modulation of the form

$F_t = F + \Delta\theta \cos 2\pi ft$

will result.

The overall transmitter-receiver frequency response was thus made substantially level over the range of 300 to 15,000 c/s. The circuit diagram of the F.M. adaptor which was constructed embodying these principles is shown in Fig. 1. A crystal oven is not shown in this diagram, but would generally be desirable in an actual installation in order to keep the crystal frequency more constant.

The actual deviation measurement was performed by connecting a panoramascope (sometimes also referred to as an "etherscope") to the mixer stage of a V.H.F. receiver. By frequency modulating the transmitter a number of sidebands are generated besides the carrier in the transmitter, which can be made visible on the panoramascope by tuning the receiver to the transmitter carrier frequency. At certain modulation indices (*i.e.*, ratios of carrier deviation to audio frequency) the carrier disappears completely, all transmission energy being transferred to the sidebands. The lowest ratio at which this occurs is 2.4048 and his fact was made use of by increasing the modulation depth from zero until the carrier disappeared on the panoramascope. The deviation is then simply given by 2.4048 f, where f is the audio-frequency.

Apart from distortion in the phase modulator, distortion in other parts of the circuit must also be considered. Unlike amplitude modulated systems, where distortion is usually due to non-linear valve characteristics distortion in F.M. systems is mainly governed by the parameters of tuned circuits and is found to be mainly due to:

(i) phase non-linearity in the tuned circuits of the transmitter and receiver, causing odd harmonic distortion;

(ii) mis-alignment of the tuned transmitter and receiver circuits, causing even harmonic distortion.

Distortion due to phase non-linearity arises because a tuned circuit no longer presents a resistive impedance, when swept through by a frequency-modulated voltage, causing either a leading or lagging current with respect to the true F.M. voltage. It is mainly confined to the third harmonic and is of a small magnitude if $\Delta F << F$. The ratio $\Delta F/F$ is increased in the I.F. circuits of the receiver, but the increased phase-linearity of double-tuned circuits with respect to single-tuned circuits mitigates the distortion due to the increased $\Delta F/F$ ratio.[4, 5]

The I.F. bandwidth of the receiver was approximately 50 Kc/s., *i.e.*, not entirely adequate for the purpose. In order to ascertain the linearity of the system distortion figures were therefore taken with:

(a) The F.M. adaptor output being fed directly into the receiver mixer stage which was used as a doubler, and the adaptor crystal frequency being chosen to suit the intermediate frequency.

(b) The F.M. adaptor coupled to the transmitter, the transmitter output being detected in the receiver in the usual way.

Test (a) eliminates distortion due to the narrow receiver I.F. bandwidth as the deviation obtainable from the F.M. adaptor only is in the region of 1.25 Kc/s. With this deviation a 2 Kc/s. note produced a 0.4 per cent. second and 0.2 per cent. third harmonic distortion respectively. This was further checked by applying two audio-tones spaced 3 Kc/s. apart to the F.M. adaptor, each tone producing 50 per cent. of the nominal maximum frequency deviation, and measuring the resultant second order inter-modulation $(f_1 - f_2)$ which is about 32 db. below the level of f_1 or f_2, and the third order inter-modulation products $(2f_1 - f_2)$ and $(2f_2 - f_1)$ which were in both cases found to be more than 45 db. below either f_1 or f_2.

With the 1 + 4 equipment in operation the crosstalk per channel—the remaining four channels being filled up with a 1 Kc/s. note—was in all cases more than 50 db. down.

The corresponding figures for test (b) were: second and third harmonic distortion 0.4 per cent. and 1 per cent. respectively. Third order inter-modulation products were then 35 db. below either f_1 or f_2. Crosstalk: nearly 40 db. down.

The discriminator used in the receiver was of the Foster-Seeley type and required careful adjustment to keep harmonic distortion down. The R.F. oscillator of the receiver was crystal-controlled for the experiments.

Further tests were carried out with the experimental equipment over a physical link, which was far from being optical. This resulted in occasional rapid fading, but the signal strength was nevertheless reasonably steady during part of the day, the radiated transmitter power being 60 watts.

A signal-to-noise ratio of 35 db. per channel could be obtained on occasions. Doubtless over a link more nearly optical, a better and more reliable field strength would be obtained and the noise level considerably reduced.

The above tests have shown that frequency modulation possesses very attractive characteristics for multi-channel work.

The author is indebted to Dr. J. H. Ferris under whose general direction the above work was carried out.

References

[1] L. S. Crutch. "A Five Channel Carrier Telephone System for the Services," *Post Office Electrical Engineers' Journal*, Vol. 38, Part I, April, 1945.
[2] K. R. Sturley. "Frequency Modulation," *Journal of the I.E.E.*, Vol. 92, Part III, No. 19, September, 1945.
[3] A. Hund. "Frequency Modulation," McGraw Hill Book Co. Inc.
[4] H. Roder. "Tuned Circuits and a Frequency Modulated Signal," *Proc. I.R.E.*, Vol. 25, 1937.
[5] J. R. Carson and T. C. Fry. "Variable Frequency Electric Circuit Theory with Application to the Theory of Frequency Modulation," *Bell System Technical Journal*, Vol. 16, October, 1937.

Improved Cathode Structure

Ceramic materials for supporting tubular cathode structures for cathode-ray tubes have been used extensively, and although these materials are satisfactory in many respects they suffer from the great disadvantage that during operation occluded gas is liberated which impairs the life of the tube.

A practical structure for supporting a pill box cathode which overcomes these defects has been developed, in which a suitable glass is used in place of the well-known ceramic supporting disks. A tube of metal such as Kovar is placed on a suitable die and an appropriate quantity of glass of the Kovar sealing type is placed around it. The whole is heated until the glass fuses, then it is shaped in the form of a disk by means of plungers. The Kovar tube is thus firmly sealed to the disk and the nickel cathode tube may then be slid inside and welded to it. It has been found that a high degree of uniformity can be obtained with the method and such structures are gas free and mechanically satisfactory.

Communication from E.M.I. Laboratories

47

ced in
ut the
theless
of the
power

db. per
occa-
more
more
ld be
l con-

n that
s very
multi-

J. H.
rection
t.

Telephone
Electrical
1945.
' Journal
ptember,

Graw Hill

requency
1937.
requency
n to the
System

---

e

orting
thode-
sively,
s are
they
antage
gas is
of the

rting a
comes
ed, in
place
orting
Kovar
nd an
of the
round
il the
in the
ngers.
sealed
thode
e and
d that
an be
such
chani-

C.M.I.
stories

A

THE new 48-page List No. 132/RD/47 is a complete illustrated guide to the many ranges of T.C.C. Paper, Mica and Ceramic Capacitors available through the usual distributive channels. Together with List No. 123/RD/46, which covers Wet and Dry Electrolytics, this new catalogue offers to manufacturers, traders and constructors a range more comprehensive than ever before. We will be pleased to send you a copy on receipt of 2½d. stamps.

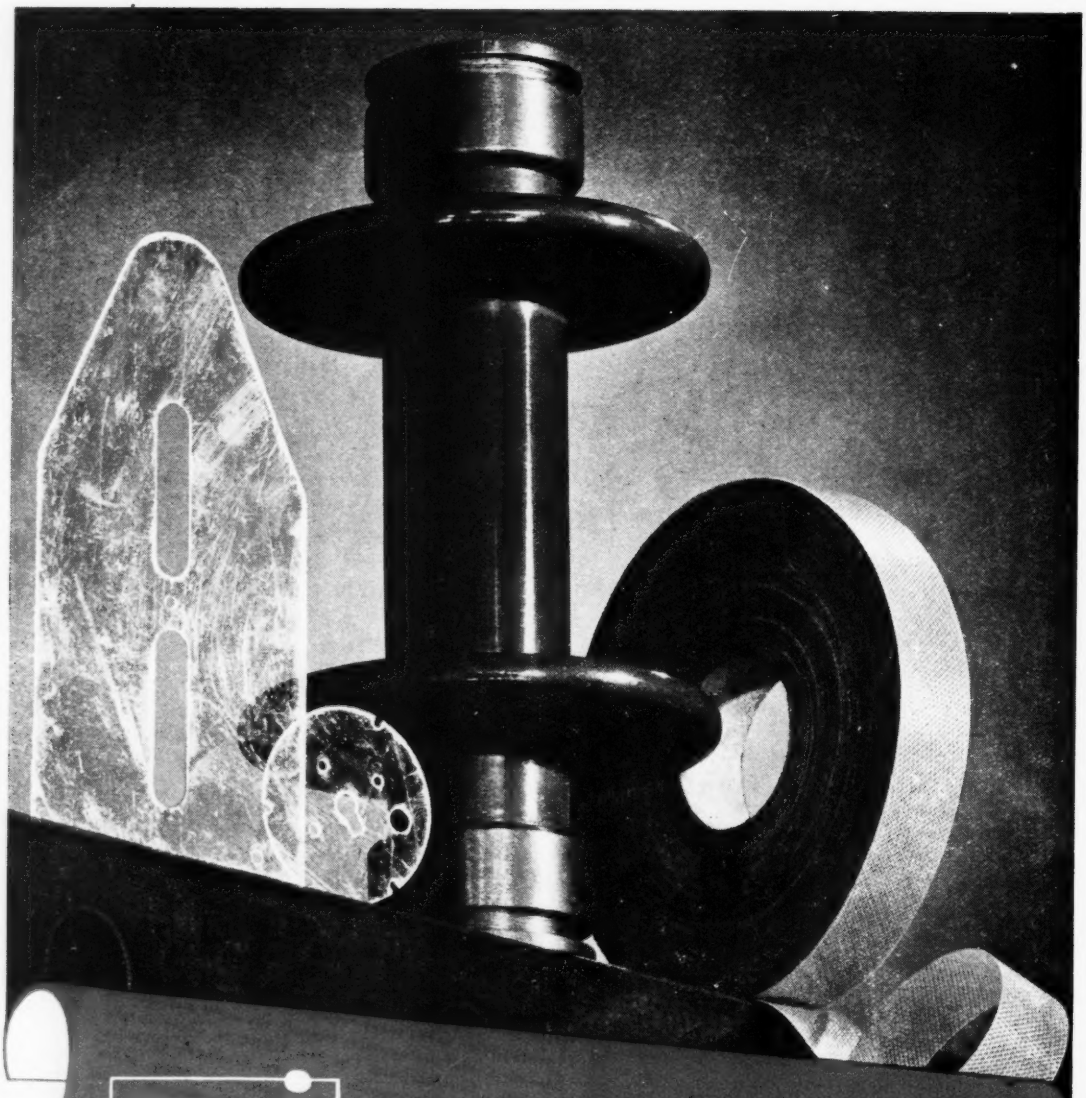
For more than 40 years, T.C.C. have been pioneers and the leading specialists in the manufacture of Fixed Capacitors.

In the best sets you'll see T.C.C.

THE TELEGRAPH CONDENSER CO., LTD.

RADIO DIVISION

NORTH ACTON · LONDON · W.3. Telephone: ACORN 0061



m and i

THE MICANITE & INSULATORS CO. LTD

Empire Works, Blackhorse Lane, Walthamstow, London, E.17

Makers of MICANITE (Built-up Mica Insulation). Fabricated and Processed MICA, PAXOLIN (Synthetic-resin laminated sheets, rods, tubes and cylinders). HIGH VOLTAGE BUSHINGS and TERMINALS for indoor and outdoor use. EMPIRE Varnished Insulating Cloths and Tapes and all other forms of Electrical Insulation. Suppliers of Vulcanised Fibre, Leatheroid, Presspahn, etc. Distributors of Micaflex-Duratube Sleevings and Kenutuf Injection Mouldings (P.V.C.)

A

a pre
The
logar
migh
law.
ing t
syste
alrea
multi
being
more
resist

In
mete
intro
flat
varia
If the
lengt
card
differ
funct
woul
a lir
slide
norm
non-l
cam

Sine

Tri
forma
since
latio
such
gunfi
putat

For
the i
gear
co-or
to th
azimu
tions
worki
the v
cosin

In
resol
obtai
the n
shaft
angul
The
propo

* B.T.H

Electrical Analogue Computing

By D. J. MYNALL, B.Sc., A.M.I.E.E.*

Part 3.—Functional Transformation

ANOTHER type of operation which is frequently needed is to cause a quantity to vary as a predetermined function of another. The function might be, for example, logarithmic or trigonometric, or might perhaps represent an empirical law. The most usual way of achieving this result in electro-mechanical systems is to employ a unit of the type already described for the purpose of multiplication, the required function being introduced by making one or more of the potentiometers or variable resistors non-linear. (Reference 12.)

In the case of resistive potentiometers, the non-linearity may be introduced by winding the wire on a flat card of constant thickness but variable depth, as illustrated in Fig. 21. If the number of turns of wire per unit length is constant, the profile of the card must be cut to the form of the differential coefficient of the required function. For example, a square law would be obtained from a card with a linear taper. Alternatively, the slider may be driven over a normal linear winding through non-linear mechanical linkages or cam mechanisms.

Sine and Cosine Functions

Trigonometrical functional transformations are of particular interest, since they enter repeatedly into calculations involving spatial relationships such as prediction for the control of gunfire, or in navigational computations.

For example, it is natural to find the information from radar tracking gear in the form of spherical polar co-ordinates, defining a radius vector to the target in terms of slant range, azimuth and elevation. Computations are usually much simplified by working with cartesian components of the vector, and this calls for sine and cosine transformations.

In A.C. systems, two-dimensional resolution into components may be obtained from small instruments of the magslip or selsyn type, in which shaft position corresponds to the angular datum of the input quantity. The excitation is single-phase A.C., proportional to the magnitude of the vector which is to be resolved, and the components appear as the outputs from two pick-up windings which are crossed at right-angles.

Repeated operations of this sort may be used to deal with three-dimensional resolutions.

Another type of element for dealing with the same problem is known as a "sine-cosine potentiometer." It is a resistive device and can take various forms.

The principle of one form, known as a "slab potentiometer," is illustrated in Fig. 22.

A rectangular card is wound uniformly with resistance wire, and a floating or balanced voltage, representing the magnitude of the vector which is to be resolved, is applied to the winding, thus setting up a uniform potential gradient substantially parallel to one side of the card. A fixed, earthed contact is made to the middle of the winding. Another contact can be moved over the winding in a circular path with the fixed contact as centre. There are two positions of the movable contact when it is at zero potential. Measuring the angular position, θ, of the movable contact from one of zeros, it is clear that its potential is proportional to the input voltage multiplied into $\sin\theta$. Another contact moving on the same path, but diametrically opposed to the first, would have an equal and opposite potential, thus completing a balanced output. A balanced cosine output can be picked up from another pair of contacts on a diameter at 90° to the first. When the full arrangement of two balanced outputs is catered for, it is usual to fix the contacts and move the card, as the number of sliprings required to allow continuous rotation is then a minimum.

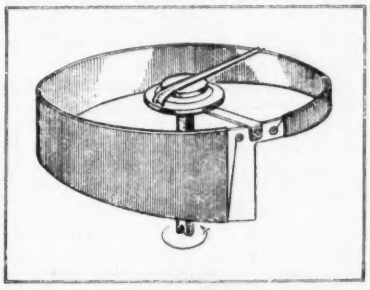


Fig. 21. Diagrammatic illustration of a type of non-linear potentiometer.

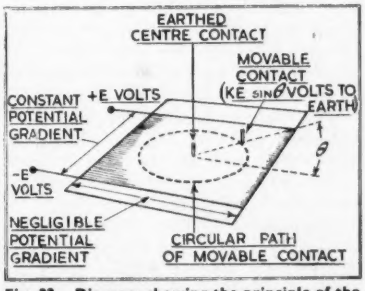


Fig. 22. Diagram showing the principle of the slab potentiometer, for producing electro-mechanical functional transformations of the sinusoidal type.

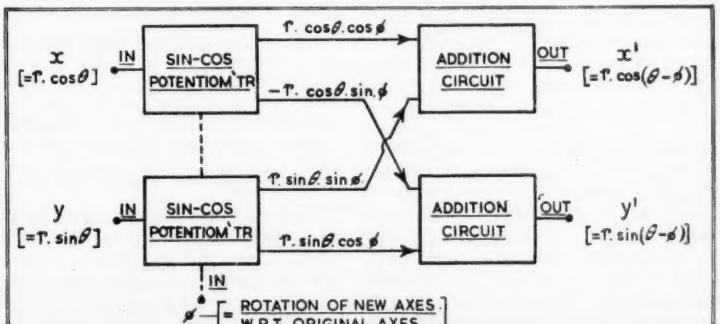


Fig. 23. Arrangement of trigonometrical functional units to perform a transformation of cartesian co-ordinates equivalent to a rotation of the axes.

* B.T.H. Electronics Engineering Dept., Rugby.

In another precision type, a pin is moved in a circular path by means of the shaft to which the angular input is applied. This pin is in continuous engagement with a straight slot in a sliding member. Thus, the displacement of the sliding member is a sinusoidal function of the input angle, and this function is multiplied into the electrical quantity representing the magnitude of the vector by the method of Fig. 8 (in its balanced form).

Rotation of Axes (Cartesian Co-ordinates)

As an example of the kind of operation which can be covered by simple arrangements of sine-cosine potentiometers, Fig. 23 shows an arrangement for making appropriate changes to the x and y co-ordinates in a rectangular cartesian system when the reference frame is rotated about the Z-axis through an angle ϕ.

Confining attention to the XY-plane, let x and y be the cartesian co-ordinates with respect to the original axes and x' and y' the corresponding co-ordinates with respect to the new axes. In addition, let r and θ be the polar co-ordinates with respect to the original origin and X-axis. Then the equivalents shown in square brackets in Fig. 23 may be written down. The diagram then shows, in terms of r, θ and ϕ, how the desired result is obtained.

The potentiometer systems are balanced to earth, and it should be noted that one of the sine outputs must be made negative by crossing over the appropriate connexions.

Mechanical shaft rotation is obviously a very suitable quantity to represent ϕ, since it admits of an unlimited number of complete revolutions in the same direction. The electrical quantities can be brought into line with a mechanical basis, if desired, by the same means as before.

A simple addition, attributable to Dr. A. Uttley, turns the unit of Fig. 23 into a means for converting cartesian to polar co-ordinates, thus providing a unit which is the inverse of the sine-cosine potentiometer itself. The x and y co-ordinates are introduced as before, but the ϕ shaft is driven by a servo motor which is controlled by the y' voltage. This results in the system turning automatically until $\phi = \theta$, in order that y' shall become zero. Thus θ is indicated by the shaft of the sine-cosine potentiometers. Furthermore, when this position has been found, $x' = r$, thus indicating the other polar co-ordinate. There is another possible equilibrium position, when $\phi = \theta + \pi$, but only one of the positions can be stable, so that in practice there is no ambiguity.

Further References

Enough has been written to demonstrate the nature of electro-mechanical computing methods, but, before leaving this field in order to examine the possibilities of pure electronics, one or two general points may be noted.

The examples have been restricted to the use of either mechanical displacement or voltage as basic quantities, in order the better to demonstrate underlying common principles which enter into the design of various types of units. References 14 and 15 provide further examples of applications of these principles.

It should not be thought, however, that these two quantities are universally used to the exclusion of all others. For example, Reference 16 describes apparatus for solving a number of simultaneous linear equations, in which the unknowns are represented by magnetic fluxes, and the coefficients by the number of turns in associated windings. Again, Reference 17 describes an electro-mechanical differential analyser in which alternating current is the basic quantity, and provides interesting examples of units suitable for this basis.

Choice of Basic Quantity

It is perhaps not out of place to pause to consider some of the factors governing the choice of a basic quantity.

Mechanical rotation has the advantage of an unlimited range of operation and the capacity for staying indefinitely where set, if required to do so. It is thus very suitable for representing angular quantities and also the integrals of quantities.

The phase angle of an alternating current or voltage has similar properties to mechanical rotation, and, in a certain sense, bears an integral relationship to frequency, but is otherwise unpromising from the point of view of computing circuit design.

Current and voltage are readily concerted one into the other, in linear circuits, and the magnitude of either has desirable properties as a basic quantity, as will have appeared from the illustrations which have been given.

The choice between alternating and direct quantities is conditioned by the application, since there are advantages and disadvantages on both sides.

Direct current or voltage has particularly simple differential and integral properties in relation to easily realised circuits, but special measures have to be taken to prevent zero errors occurring in amplifiers.

Alternating current or voltage offers no amplifier zero problem, but fundamentally cannot deal with changes occurring inside the time of one period. This calls for a fairly high supply frequency, in some instances, and it may be difficult to prevent unwanted phase shifts and stray pick-up. Furthermore, it is not always possible to stabilise A.C. servo systems satisfactorily, without undue complication. The possibility of using the two winding transformer and magnetic resolving elements is a distinct advantage of A.C. systems.

Ultra High-Speed Operation

In any automatic computing system the speed of operation is ultimately limited by the acceleration which can be imposed on the active elements. In this respect electronics is unique. Nothing is known to Science which can be more readily accelerated than the electron.

In electro-mechanical systems the overall speed of operation is ultimately limited by the inertia of the mechanical elements. Even with the lighest of servo-mechanisms, rates of variation of the data cannot be dealt with at levels even distantly approaching the speed at which electronic devices, such as the thermionic valve, the cathode-ray tube and the photo-electric cell, can operate.

The introduction of electricity into computing systems offers two main advantages. The first of these is realised in electro-mechanical systems, and is the feature of flexibility of design and layout. The second of the advantages is the possibility of operating the whole system at " electronic " speeds.

It has already been mentioned that electronic digital computing is being actively explored on a grand scale.

On the other hand, as far as the writer is aware, no indication of an equally determined attempt to realise fully the potentialities of electronic analogue computing has yet been published, though it is unlikely that this line of development is not receiving considerable attention.

The remainder of this article is

devoted to outlining a possible line of attack on this problem.

The possibility of dealing with fast-changing data, outside the speed capabilities of existing systems, is an obvious feature of ultra-high-speed technique. A less obvious, but nevertheless valuable, advantage could result from its application to devices such as algebraic equation solvers and differential analysers, where the substantially instantaneous presentation of the result of changing any of the conditions in the problem would greatly facilitate searching for desired types of solutions.

The means which have already been described for dealing with addition do not involve mechanical elements, so that it is unnecessary to consider this process anew.

Since the principles on which electronic time differentiators and integrators may be constructed are well established, these are described first.

Electronic Time Differentiation

Fig. 24 shows a simple and well-known form of electrical time differentiator. Its action is not exact, since it has a high-frequency cut-off in the neighbourhood of $1/2\pi CR$ cycles per second, but it can be made as nearly exact as desired by reducing the value of the CR product. The penalty paid for increased accuracy is decreased output. The principle is simple. The

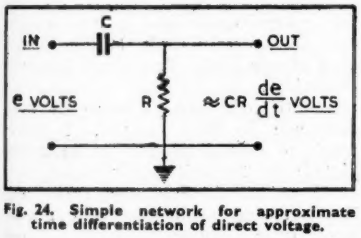


Fig. 24. Simple network for approximate time differentiation of direct voltage.

design must be such that the output voltage is always small compared with the input voltage. This being so, practically the whole of the input voltage is applied to C and the current in C is approximately equal to C multiplied by the time rate of change of the input voltage, in volts per second. This current flows through R and gives the output voltage shown on the diagram.

Fig. 25 shows how a considerable improvement can be made by replacing the resistance R by a transresistance of the type shown in Fig. 5. As shown, the output is of the same level as in Fig. 24, but the low input resistance of the feedback unit ex-

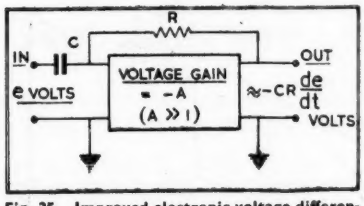


Fig. 25. Improved electronic voltage differentiator employing the feedback principle.

tends the frequency range by the factor A. If desired, some of this gain of accuracy may be sacrificed in order to improve the output level.

The examples given are, of course, not suitable for working on an A.C. basis. Circuits for the approximate differentiation or integration of the envelope of an A.C. quantity are known, and are of considerable use in servo stabilisation. They will not be discussed here, however, as their usefulness in precision computing circuits is somewhat limited. This is because they have the fundamental limitation that the action approaches perfection only when the modulation frequencies are small compared with the carrier frequency and the practical disadvantage that component values must be accurately related to the carrier frequency.

It is also possible to use the properties of an inductive element to produce a voltage which is proportional to the time rate of change of an applied current, but this method is not so generally useful as the one which has been described. This is due to the impracticability of obtaining a self-inductance of the same degree of purity as a capacitive element (thus necessitating the use of mutual inductance or a means of effectively balancing out the loss in a self inductance) and also to the fact that the effects of stray capacitance are more serious in an inductive circuit.

Electronic Time Integration

Fig. 26 shows the type of integrator which is similar to the differentiator of Fig. 24. Again, the action is not

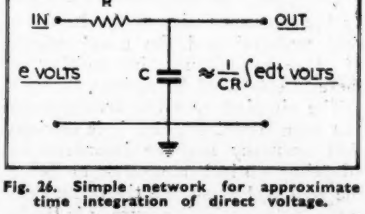


Fig. 26. Simple network for approximate time integration of direct voltage.

exact, since there is a low-frequency cut-off in the neighbourhood of $1/2\pi CR$ cycles per second. In this instance the CR product must be raised to improve the accuracy, and, as before, increased accuracy must be paid for by decreased output level. The design must be such that the output voltage is always small compared with the input voltage. Thus, practically the whole of the input voltage is applied to R and causes current, approximately equal to $1/R$ multiplied by the input voltage, to flow into C. This current builds up a voltage on the condenser proportional to its time integral, as indicated on the diagram.

The feedback method of improving the performance, analogous to

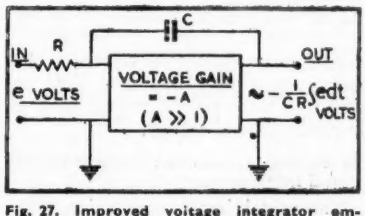


Fig. 27. Improved voltage integrator employing the feedback principle(Blumlein integrator).

Fig. 25, is shown in Fig. 27. With the proportions shown, the output level is the same as the simple circuit, but the low-frequency cut-off is depressed by the factor A. The improvement results from the fact that the effective input impedance presented by the feedback unit to the current flowing from the resistor is equivalent to that of a condenser which is approximately A times as large as the feedback element. The deliberate use of this effect to provide an electronic integrator is attributable to the late A. D. Blumlein

As before, the use of inductive reactance to provide a time integrator is possible but usually disadvantageous.

Any device working on a voltage or current basis, such as the integrators of Figs. 26 and 27, has, for obvious practical reasons, limits to its range of output. When this fact is coupled with the characteristic low-frequency cut-off, it appears that such integrators cannot continue to integrate indefinitely in the same direction, nor can they hold an output level indefinitely. In these respects they are fundamentally inferior to the electro-mechanical integrator on a mechanical basis which was described earlier. However, they are well

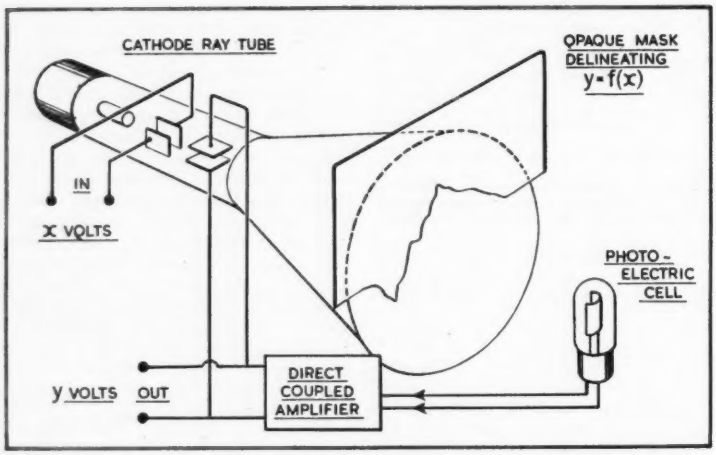


Fig. 28. Electronic arrangement for producing a direct voltage functionally related to another direct voltage.

suited to transient or repetitive inputs, which they can deal with at speeds which no electro-mechanical integrator could follow.

Electronic Consistent Differentiation and Integration

The principle of constructing units on a consistent basis from the time differentiators and integrators which have been described has already been laid down. For this purpose, it will be remembered, multiplying and dividing units are needed. However, it is convenient first to deal with electronic functional transformation, as this has a direct bearing on the design possibilities for the required units.

Electronic Functional Transformation

The outline of a means for performing electronic functional transformation, which has been successfully tried out qualitatively, is shown in Fig. 28.* It is a scheme for producing a dependent variable voltage, y, which is a chosen function of an independent variable voltage, x. The function must be single-valued (at all events, in the simplest embodiment of the idea), but is otherwise arbitrary.

A curve representing the desired function is drawn in the ordinary way in cartesian co-ordinates. A mask is made from this curve and placed as shown in the diagram, the axes to which the curve is drawn being aligned with the X- and Y-axes of the cathode ray tube.

A photo-electric cell is placed in front of the whole arrangement so as to collect light from the cathode ray tube spot when this is not obscured by the mask. The photo-electric cell, which is of a standard type, is connected to the input terminals of a high gain D.C. amplifier, the output terminals of which are coupled to the Y-plates of the cathode ray tube. Alternatively a multiplier photo-cell may be used, when the gain of the amplifier need not be high, its chief function being the production of a sufficient deflecting voltage for the cathode ray tube.

The amplifier is so designed and connected that, in the absence of light to the photo-electric cell, the spot of the cathode ray tube would be deflected off the bottom edge of the screen, while the input of full light from the spot would be sufficient to provide a Y-deflection off the top edge of the screen. This results in the spot coming to rest partially obscured by the edge of the mask. Thus, whatever be the applied X-deflection (independent variable), the spot "sticks" on the curve, and a voltage will be found on the Y-plates which is dictated by the ordinates of the curve (dependent variable).

The speed of operation is limited by the characteristics of the luminescent material and the usual effects of stray capacitance, but neither of these effects need be serious.

The simplest possible arrangement has been described, but it is obvious that accuracy may be improved by adopting optical measures to bring the spot and mask effectively into the same surface. This accuracy is likely to be well maintained, since it is controlled chiefly by the deflection characteristics of the cathode ray tube, which are relatively stable.

For the sake of effecting a straightforward introduction to the action of the unit, it has been assumed that the mask is cut without special reference to the particular cathode ray tube to which it is to be applied. It is clear, however, that, for the most precise purposes, it would be practicable to cut the mask to a curve dictated by the spot pattern which is obtained when the pairs of voltages which define the function are applied to their respective deflecting plates. This would, to a first order, eliminate geometrical errors arising from peculiarities in the cathode ray tube construction or in any optical system employed.

*Independently invented by D. M. MacKay and the author at about the same time.
See *Nature* Vol. 159, p. 406, (1947) and *Nature* Vol. 159, p. 703 (1947).

REFERENCES

[14] Herr, D. L., and Graham, R. S.: "An Electrical Algebraic Equation Solver," *Review of Scientific Instruments*, Oct., 1938.
[15] "Industrial Control: Electronic Flight Trainer," *Electronics*, Sept., 1946.
[16] Mallock, R. R. M.: "An Electrical Calculating Machine," *Proc. of the Royal Society*, May 3rd, 1933.
[17] Varney, R. N.: "An All-Electric Integrator for Solving Differential Equations," *Review of Scientific Instruments*, Jan., 1942.

(*To be continued*)

Degrees for ex-Service Men

Mr. O. S. Puckle writes:

With reference to my recent letter on Science and Engineering Degrees for ex-servicemen and others which you kindly published, I should be glad if you could find space for the following:

"With reference to recent correspondence in this column, I have received a total to date of 93 completed questionnaires. Of these, 51 are from the London area, including Dartford and South-west Essex, and ten from Stoke-on-Trent. The numbers in each of the other localities are unfortunately too small to make it possible to ask the Ministry of Education to take action, but it is hoped that in London and Stoke it may be possible to bring about the desired results.

"I am communicating with the Ministry of Education, to whom the questionnaires and an analysis of the results is being sent.

"I should like very much to thank those who have completed questionnaires and to request that those to whom they have been sent and who have not yet returned them would do so immediately, especially if they wish to take courses in the London area or in Stoke."

Radar for Mersey Harbour

At the recent International Meeting on Radio Aids, held in America, a short account of the Harbour Radar Installation for the Port of Liverpool was given by **Capt. H. V. Hart** (Mersey Docks & Harbour Board) and **R. F. Hansford** (Sperry Gyroscope Co.).

The following summary gives a brief review of the special requirements of such an installation and the development of suitable apparatus, and is published with acknowledgments to the Ministry of Transport, for whom the original report was prepared.

"A PORT Authority issues an invitation to shipping to utilise its accommodation and facilities. It is plainly the duty of a port to offer shipping, as far as reasonable and in the port's own interests as far as possible, safe approach, entry, departure, anchorage, and access to dock accommodation where these amenities are required."

The harbour radar installation now being constructed for the Mersey Docks and Harbour Board has been designed to meet these requirements and supplement the facilities already offered by the port.

It should be realised, however, that a radar port installation is not intended for the purpose of "control"—in fact, no Port Authority would take the responsibility of controlling the navigational movements of vessels within its area, even with the consent of pilots or masters who are actually responsible for the safety of their craft.

The use of harbour radar is as a source of information for both the Authority and the captains of vessels to supplement their knowledge of existing conditions and the movement of vessels in the channel, particularly in bad weather.

Where the port is situated on a river or estuary having a long and circuitous approach channel its requirements will be more stringent than in a port with a short approach channel or on the sea-board. Such a port can be adequately served with a large general radar display and an expanded sector of a selected area at short range.

The Mersey Harbour approach (Fig. 1) has a channel 12 miles long and therefore provides one of the major problems for radar cover.

The site selected in Liverpool is at the mouth of the Mersey on the dock estate, and with the exception of a small area of the southward portion of the river, covers the area of the bay, the sea channels and sea approaches.

Requirements of Radar Equipment

In view of the length of the approach channels to Liverpool and their narrowness, the equipment provided needs a very high discrimination, and this was set at better than 1° in bearing by about 40 yards in range. To facilitate ease of reading, the displays should be of large scale, and 1 in 30 or 40 was considered satisfactory.

In conditions of high shipping density, some means must be provided for distinguishing between ships and navigation buoys, and the position of the ship must be fixed with speed and accuracy. Further, the equipment must be capable of being operated by a single non-technical official, who will also be responsible for communicating with the ships. This means that the equipment must be straightforward to use and give clear unmistakable pictures. Provision must also be made for remote indication in, for example, the Marine Surveyor's office. Finally, such maintenance as is necessary should be carried out by a radio mechanic and not require a skilled technician.

Projected Equipment

The equipment which has been planned to meet the requirements given above will be sited at the N.W. corner of Gladstone Dock commanding a view of Liverpool Bay and the estuary of the Mersey as far as the Princes Landing Stage.

In order to achieve the bearing discrimination required a large aerial scanner has been designed, to be mounted at the top of an 80 ft. tower. The aerial mirror is on top of a cabin containing the driving mechanism and bearing transmission units, which enables an engineer to attend to the motor and gearing in comfort. The mirror is fitted with heaters to prevent icing-up.

At the foot of the tower the remainder of the equipment is housed in a building which also contains the

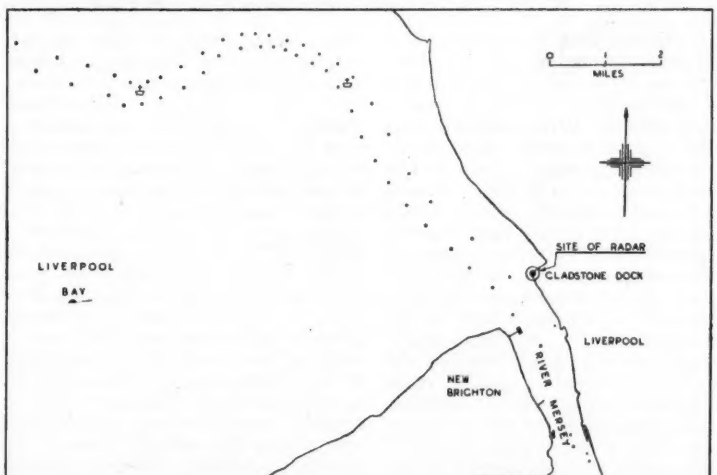


Fig. 1. Approach to the Mersey Harbour, showing channel.

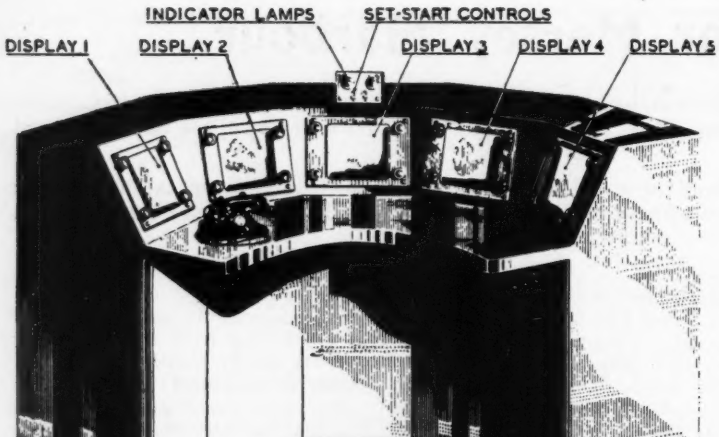


Fig. 2. Display console, giving five views of channel.

display consoles. This contains five displays, the first giving a general view of the bay and the remainder giving details of selected parts of the channel. (Fig. 2.)

The detailed displays are of a new type, showing a precision picture of the limited arc and range interval which it is desired to inspect and which show a true plan presentation. All four displays will be set up to the same scale and will slightly overlap one another in range, so that an uninterrupted view of the area is obtained which is larger than could be accommodated on a single C.R. tube. Each tube will have a chart of the area in front of it, and a rectangular grid for map plotting, a corresponding grid being on the map itself. This enables the bearing and position of a vessel to be fixed more rapidly than by the use of range and bearing strobes.

The grid reference can also be communicated to the vessel direct, without the necessity for previous plotting on the chart.

In an adjoining room of the building will be installed the Harbour Board's W/T and R/T communication equipment, with provision for remote control from the radar console. The power generators and stand-by diesel generator are in a separate building near the main station.

Application to other Ports

There are many ports throughout the world where the facilities will be increased by the use of such radar equipment, and many of these will not require such high discrimination as Liverpool. It is probable, however, that at least 1° will be necessary. The number of displays will depend on the length of the approach channel or other geographical features.

It is suggested that the equipment is sufficiently flexible to enable it to be used elsewhere, and special adaptations can be designed to meet requirements in the most efficient way.

Liverpool will be the first port in the world to install such an equipment, and the Mersey Docks and Harbour Board and the Sperry Gyroscope Co. are proud to have initiated a system which may become standard for the major ports of the world.

Radio Interference from Industrial R.F. Heating Equipment—*concluded.*

ing problem is that of filtering. The attenuation produced by a given screen can be materially reduced if a lead entering the screen is inadequately filtered. Using standard components insertion losses of 60 db or more can be obtained over a frequency range 0.5 to 20 Mc/s. from a simple low pass filter, which should be adequate for most single screened compartments. With high powered equipment the problem of protection against filter breakdown becomes important, as a fault current in the filter which could cause appreciable damage, might be much less than the normal load current and normal overload protecton would not operate. Present practice is to use a fuse in series with each capacitor connected to the supply network, but the inductance so introduced in series with the capacitor increases its impedance at high frequencies and impairs the filter efficiency. The best solution appears to be the operation well within their voltage rating of the minimum number of high-grade low-inductance capacitors without fuses, preferably "bushing" or "feed through" types when the frequency is of the order of several megacycles. By this means, effective filtering may be obtained with the minimum chance of breakdown.

Conclusions

The results, while not leading to any conclusion regarding the solution of the interference problem, serve to indicate its magnitude in the case of unscreened or partially screened equipment. Two solutions have been proposed, frequency allocations for free radiation, and adequate screening. The evidence here is in favour of adequate screening, at least in the case of small equipments where frequency drifts would necessitate the allocation of wide bands to cover the frequency drifts observed and the harmonic frequencies radiated. The provision of means to stabilise the frequency within a narrow band and to attenuate harmonic frequencies would be more costly than the provision of adequate screening and filtering, since the natural protective metal cabinet may be made to provide most of the screening required.

Although a considerable measure of alleviation can be achieved by fairly simple means, the present demand for R.F. heating equipment, due to its advantages for some industrial processes, renders the possibility of interference a real problem. It is understood that a code of practice is being drawn up by the I.E.E. and B.S.I. to give guidance on the screening and filtering methods required for reasonable protection. At present, statistics regarding complaints of interference traceable to this type of equipment are not available, but it is certain that, in the future, the interference problem will grow unless precautions are taken.

Carbon Black—*Its Types, Properties, and Uses*

By G. FITZGERALD-LEE

ALTHOUGH the use of carbon black in some way or another is known to most scientists, engineers, and others, they are mostly unaware of the very wide use of this commodity, essential in many industries. Its application now ranges from the fine arts and literature to building materials and even the making of chocolate; and, further, there are available to-day many different types of carbon, mineral, animal, and vegetable blacks, numbering altogether over one hundred. This has naturally led to a certain amount of confusion in industry, which has necessitated, in order to eliminate further confusion, the separation and classification of these various blacks according to their origins.

Definition

Due to carbon black being an extremely finely-divided organic substance, it has been given the chemical epithet of "colloidal carbon" to distinguish it from all others which, no matter how finely they are divided, are not colloidal but remain crystalloid. Carbon black is a trade name given to the finely-divided carbon produced from burning hydrocarbons such as mineral oils, in conditions where combustion is incomplete. The term strictly includes all grades of lamp black, furnace, thermal, and acetylene blacks, and impingement blacks, but not the non-colloidal blacks. Carbon black is not pure carbon, but is from 80 per cent. to 90 per cent. carbon, by weight; it is chemically inert but physically very active. Generally speaking, the low volatility of a black indicates a high carbon content, and vice versa.

To eliminate the confusion which had arisen from conflicting designations which were being given to the many varieties of blacks, the Office of the Rubber Director of the United States set up, in 1943, a Committee on carbon black nomenclature. The chairman of that committee, W. B. Wiegand, of the Columbian Carbon Co., New York, who was also the originator of the term "colloidal carbon," suggested a classification of carbon blacks, which it would be hard to improve. Wiegand graded the carbon blacks according to types, method of production, quite irrespective of physical properties or applications.

Types of Black

The Wiegand classification was in five groups or types: Channel or impingement blacks, furnace blacks, thermal or thermatomic blacks, acetylene black, and lampblack.

Channel or impingement black is made by the channel, disk, or roller process, by the impingement of natural gas or other hydrocarbon gas flames on a cool surface, and removal by scrapers of the black deposited. The four Channel grades are Conductive (C.C.), Hard Processing (H.P.C.), Medium Processing (M.P.C.), and Easy Processing (E.P.C.).

The *Furnace* type is made by the furnace-combustion process. This is effected by the incomplete combustion with a limited supply of air in a free flame, without impingement, of natural gas or natural gas enriched with oil vapours, and recovery of the black carried away with the hot gases in a cooling and collecting system. There are four Furnace grades: Conductive (Aeroplane tyres) (C.F.), Fine (F.F.), High Modulus (H.M.F.), and Semi-Reinforcing (S.R.F.).

The *Thermal or Thermatomic type* is produced by the Furnace-thermal-decomposition process, by cracking natural gas, or other hydrocarbon gases, at hot surfaces in the absence of air. This type has Fine (F.T.) and Medium (M.T.) grades.

Acetylene black may be produced from acetylene gas by one of three means: thermal decomposition at 800° C.; explosion started by an electric spark in a closed vessel under a pressure of two or more atmospheres; or from methane by its decomposition in the electric arc. Acetylene, or "Shawinigan" Black is in two grades: Standard and Hiflo.

Lampblack is made by burning heavy petroleum oils or coal tar products (creosote, naphthalene, or anthracene) in free flames and collecting the soot produced, away from the flame. It has five grades: Heavy, Light (R.M.V.), Velvet (L.B.V.), Witco, and Monsanto.

Carbon black, an essential ingredient in automobile and aeroplane tyres, is the best known reinforcing material for all kinds of rubber tyres. The rubber industry uses about 90 per cent. of all the carbon black produced. Natural rubber tyre tread mixes contain 50 per cent. by weight of impingement black, and synthetic rubber tyre tread mixes about 70 per cent.; in most other applications twice as much carbon black is used in synthetic rubbers than in ordinary rubbers. Electrically-conductive rubber is made by the incorporation of carbon black.

Uses

Carbon black is widely used in printing, paper, and similar trades. Printing ink is a mixture mainly of carbon black and mineral or linseed oil, and Indian ink is lampblack and parchment size or fish glue, rubbed down with water. Carbon black is the only pigment suitable for colouring the fast flowing and quick drying news ink in high-speed rotary printing presses; the drying is partly by penetration into the paper, and partly by oxidation. Carbon black is used for photographic black protection paper and other black and grey papers. Carbon paper is a paper coated with waxes containing carbon black; it is also used in various glazed papers. Black crayons, paints, varnishes, lacquers, enamels and dopes all use carbon black, the dopes being the subjects of the only two official specifications (British) on the commodity; B.S.S. 284 and 2.D.30. B.S.S. 284 (1937, amended 1940, 23pp., 3s. 6d.), "Black (carbon) pigments for paints" covers a description of the material, content of coarse particles, oil absorption, colour, staining power, matter volatile at 100° C. (98° C. to 102° C.), ash, ether extract, matter soluble in water; sampling technique and methods of carrying out the appropriate determinations are described in the Appendices. The Specification Booklet includes B.S.S. 285-8 (Bone, Vegetable, Lamp, and Mineral Blacks) as well as 284.

Carbon black is also used in the making of stove polishes, shoe polishes, gramophone records, typewriter ribbons, linoleum, and artificial leather. In building is is used for colouring cement, mortar, artificial stone, and tiles. In the United States and in Germany carbon black is com-

(*Continued on page* 266)

NOTES FROM THE INDUSTRY

The Radar Association

Originating with an idea of F/Lt. C. W. Knight, a Radar Association has been formed with an initial membership of over 2,000. The president is Air Commodore A. L. Gregory, M.B.E., and among the vice-presidents are Air Vice-Marshal R. Aitken, C.B.E., and Group Captain Dorté, O.B.E. (now of the B.B.C. Television Staff).

Quoting from the announcement; "There are no ranks . . . the ex-airmen buy air-marshals beer and *vice versa*" (a new form of Coca Cola? —ED.)

All R.A.F. radar staff are invited to get in touch with the hon. secretary, Mr. C. Knight, 31 Currey Road, Greenford Green, Middlesex.

Bendick Radio Receivers

Now available in the home market are Bendick radio receivers manufactured by Bennett Power Products, Ltd., Gerrards Cross, Bucks. The SUM/646 is a five-valve universal A.C./D.C. model covering three wavebands. It is housed in a metal cabinet bands (13-120, 120-200 and 200-600 metres). A 9-in. high-fidelity moving coil speaker gives 2½-3 watt undistorted output, and provision is made for a gramophone pick-up. The receiver is housed in a metal cabinet and can be supplied in a variety of pastel shades. The price is £22 9s. 3d. plus £4 19s. 10d. purchase tax. This company are also producing a 4-valve midget receiver which retails at £11 11s. plus £2 11s. 4d. purchase tax. Sole world distributors for Bendick receivers are Stamm and Partners, Ltd., 59 St. Martin's Lane, London, W.C.2.

Capacity Insulation Flash Tester

This useful piece of equipment allows the insulation resistance of condensers to be checked at extremely high speed. The standard model imposes a test voltage of 2,250 D.C. on the condenser and the passed/reject insulation resistance indication on the magic eye is set at 10,000 megohms so as to conform with I.S.C.C. specification. Models using other values of test pressure are available to special order. No high tension can be applied until the two remote push-buttons are depressed, thereby ensuring the operators hands are completely clear of the high-voltage parts.

Price £50. Full particulars from *Labgear, Ltd., Willow Place, Fair Street, Cambridge.*

Efficient Spring Winder

The Acru Electric Tool Manufacturing Co. announce the production of a universal spring winder for any thickness of wire up to 2½ mm. The distance between turns can be preselected and maintained by a simple tapered disk, and the wire is fed to the mandrel through the handle of the winder to ensure safety from accidents in winding.

Price £1 18s. Box of assorted wire lengths 15s.

The Acru Electric Tool Manufacturing Co., Ltd., 123, Hyde Road, Ardwick, Manchester 12.

Literature Received

"Radio Frequency Ceramics." (*Bullers, Ltd., 6 Laurence Pountney Hill, Cannon Street, E.C.4.*) The Bullers range of ceramics is fully described in their new catalogue, an excellent table at the front of the booklet giving details of the properties of each material, and sectional drawings shown the dimensions of coil formers, condenser bars and plates, feeder cones, terminal bushes and the many other component parts

Cinch Radio Parts. (*Carr Fastener Co., Ltd., Stapleford, Nottingham.*) This latest addition to the Carr Fastener Co.'s catalogue lists battery plugs and sockets, cabinet back fasteners, coaxial plugs and sockets, coil can clips, condenser pulleys, valve holders, valve retaining clips, visual tuning indicator sockets, etc. The pages are well illustrated, and detailed drawings show the constructional details of the various components. The Carr organisation is essentially one for mass production and all contacts, tags, eyelets, valve pins and a multitude of complicated pressings are produced on single machines at the rate of 150 per minute or more. Sole representatives for Cinch products are Benjamin Electric Limited, Brentwood Works, Tariff Road, Tottenham, N.17.

A.B. Rotary Lever and Miniature Switches. (*A.B. Metal Products, Ltd. Great South West Road, Feltham Middlesex.*) The first part of this catalogue is devoted to the American "Oak" type wafer, lever and control switches.

Also illustrated in the catalogue is the A.B. "Minibank" rotary wave change switch; this is a miniature one-bank switch, the overall dimensions of which, including wire soldering terminals, are ¾ in. diameter by 13/16 in. long, inside the panel.

New Ecko Universal Receiver

E. K. Cole, Ltd., announce the release of Model U49, the universal version of their popular A23. The new receiver is a 4 + 1 Superhet with 3 wavebands, press-button and manual tuning, 4-position tonal balance switch. For operation on 200/250 V 40/80 cycle A.C. mains or 200/250 V D.C. mains.

It incorporates the following features: Edge-lit glass tuning scale calibrated in three colours; 5 press-buttons of new design; improved short-wave performance with the addition of television sound; tuning unit rubber-mounted to minimise microphony.

Price: 22 guineas (plus purchase tax £4 19s. 4d.; inclusive price £28 1s. 4d.

Carbon Black

(*Concluded from page* 265)

monly used in concrete for colouring roads grey, thus preventing the road glare which is the cause of so many accidents, and also thereby making driving much easier generally.

Other uses for carbon black include electric arc carbons, insulating oils, tarpaulins, plastics, and in the case-hardening of steel; even certain types of dark chocolate for eating contain very fine, doubly-sifted carbon black as colouring matter.

Acetylene black is especially used for dry cells, electric batteries, and commonly in the place of graphite.

An interesting development of carbon black production technique was announced recently when the president of the Goodrich Company of the U.S.A. stated that in the research laboratories of his firm, a fine white powder had been produced from sand which showed indications of being able to reinforce rubber. The substance is ethyl silicate, an organic silicate produced by impingement. It is doubtful whether this "white carbon black" will ever actually replace carbon black for reinforcing rubber, but it may be a useful accessory, or may even have its own intrinsic values which have not yet been made apparent.

Carbon black will continue to be used widely in rubbers, paints, and so on, and in some spheres, such as plastics and electronics, its use is likely considerably to increase; the industry is firmly established for a long time to come.

The B.B.C. O.B. Television Unit and Camera.

TELEVISION COMMENTARY

TELEVISION has a year's achievement to record since its post-war resumption in June 1946. The year began and ended with two spectacular public events, the Victory Parade and the Trooping of the Colour. Such programmes demonstrate television's largest possibilities. Largest, because, in the first place, they provide something unique, participation in distant events by a very large number of people, (comparatively speaking); secondly because the spectators of such events are not selective like the enthusiasts for particular types of programmes; and thirdly, because they create an almost uncritical satisfaction. Here there is not striving after a new art form. In broadcasting actualities, television performs its straightforward task as a medium for making the viewer a spectator. It is to be deplored that at present television commentaries are frequently unequal to the pictures they are meant to elucidate.

In the televising of big sporting events, there has been considerable experiment in the placing of cameras in the best available positions, which cannot always be the ideal positions. The camera, as well as the player, pursues the elusive ball, and the viewer at intervals loses the pattern of the game. At the international football match at Highbury in May, the camera satisfactorily surveyed almost the whole field from a viewpoint behind one of the goals. At the Cup Final at Wembley the camera unavoidably faced the sun.

Plays give the greatest scope for production technique and every device yet available seems to have been tried, sometimes as a delicate interpretation of feeling or situation, sometimes too obviously for experiment's sake. Fading, superposition of images, double images, shadows, negative images, have all been skilfully exploited. Some of the most memorable plays of the year have been just simply good plays, well cast and acted, such as "The Man Who Came to Dinner." Nevertheless, television offers almost unbroken soil for playwrights who will study its limitations and help to develop techniques for overcoming and making use of them.

Picture quality is still very variable though normally good. It is rather unfortunate that the viewer is not told of the present limitations to television development. We believe that all the engineering equipment is pre-war and some of it of an experimental nature, and that there has not been much development since 1939. Can we expect improvements or more consistency in picture quality during the coming year, now that the B.B.C. has been able to settle down after the long interval of the war? Viewers take a keen interest in the background of the television service in all its aspects. Many feel that they would like to participate in viewer research of a parallel kind to the present listener research.

JEAN BARTLETT.

Diode Voltmeter

VOLTAGE RANGE
0.1 to 150 volts.

FREQUENCY RANGE
50 c/s – 250 Mc/s.

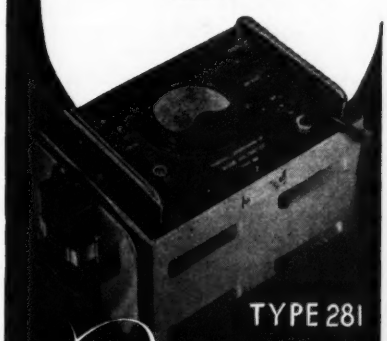
ACCURACY
± 2% of F.S.D.

ZERO SETTING
Stable, and remains precisely set on all ranges.

Alternative model available with additional D.C. voltage ranges up to 300 volts.

Delivery from Stock.

PRICE £50.



TYPE 281

Furzehill
LABORATORIES LTD.
BOREHAM WOOD HERTS
TELEPHONE ELSTREE 1137
FHL

MELTON METALLURGICAL LABORATORIES LTD.

Liquid Silver

Platinum & Gold Solutions

For Metallising Mica Ceramic Quartz etc.

Low Melting Point Solder and Non - Corrosive Liquid Flux (A.I.D. Approved)

IPSWICH ROAD TRADING ESTATE SLOUGH, BUCKS.

'Phone: Slough 20992

Agents for Australia :
A. S. HARRISON & CO. PTY. LTD.
85 CLARENCE STREET, SYDNEY

THESE ARE IN STOCK

THE RADIO AMATEUR'S HANDBOOK, published by the A.R.R.L., 12s. 6d. Postage 8d.

RADAR ENGINEERING, by Donald G. Fink, 35s. Postage 8d.

THE RADIO ENGINEERS' HANDBOOK, by F. E. Terman, 35s. Postage 9d.

TELEVISION RECEIVING EQUIPMENT, by W. T. Cocking, 12s. 6d. Postage 4d.

ULTRA HIGH FREQUENCY TECHNIQUES, ed. Brainerd, 28s. Postage 8d.

COMMUNICATION ENGINEERING, by W. L. Everitt, 27s. 6d. Postage 8d.

MATHEMATICS FOR ELECTRICIANS AND RADIOMEN, by Nelson M. Cooke, 22s. 6d. Postage 8d.

THE WIRELESS WORLD VALVE DATA, 2s. Postage 2d.

THE RADIO TUBE VADE MECUM, by P. H. Brans, 12s. 6d. Postage 6d.

ELECTRONICS FOR ENGINEERS, by Marks & Zeluff, 30s. Postage 9d.

We have the finest stock of British and American Radio books. Write or call for complete list.

THE MODERN BOOK COMPANY
(Dept. E.6)
19-21, Praed Street, LONDON, W.2

BOOK R

Capacitors — Their use in Electronic Circuits

M. Brotherton, (D. Van Nostrand Company Inc. New York, 1946). MacMillan & Co., 16s. 6d., viii + 107 pp. 33 figs.

If the valves are the heart of an electronic equipment, then to continue the analogy, the condensers are certainly the circulatory system. But perhaps we should have said " capacitors," not condensers because, as Dr. Brotherton says, the newer term is in accordance with present day standard definitions. However, the older one is the more familiar and comes much more readily off the pen. This book deals in a general way with all types of condensers and is the latest of the admirable series issued from the Bell Telephone Laboratories, where the author specialises in wave filter and condenser development. It is explained that the book is not an exhaustive treatise but is in the nature of an answer to the routine questions about condenser types and their electronic uses which crop up from day to day.

This statement really sums up the scope of the volume; it does not give detailed information on any one type of unit but does say something about every type and in particular gives a clear picture of the desiderata which lead to the choice of a condenser for a definite application. The first few chapters deal with theoretical aspects of condensers, behaviour with D.C. applied, A.C. applied, etc., and with the precautions necessary to ensure long life of service—a figure of 12 to 15 years under continuous voltage is quoted as a reasonable long life expectation. Following are chapters each devoted to individual condenser types. The emphasis is naturally on fixed condensers, variable units being dismissed in a page or two. An omission which seems serious in these days of press-button receivers and circuits with fixed condenser tuning is the lack of discussion of drift and stability in low capacity components. Temperature coefficient is certainly dealt with, but what is perhaps more important is the random drift of capacity experienced with some types and the " flutter " effect. Another chapter covers those synthetic organic dielectrics such as chlorinated naphthalene and polystyrene, which are just finding their way into condenser manufacture and the book ends with a key to the selection of condensers and examples of their use.

Written in a readable and not too advanced style, the book offers good advice both to the experienced engineer and perhaps more especially to the newcomer to the electronic field. It is useful in being possibly the first overall collection of condenser information which hitherto has been hidden in a variety of literature sources and has needed considerable finding.

E.D. HART.

Electronic Developments

R. G. Britton, D. Phil. (George Newnes Ltd.) 206 pp. 74 figs. 7s. 6d. net.

In an era of continuous electronic development, any book written in the present year by such a well-known authority as Dr. Britton will be eagerly sought by the many who want to bring their general knowledge up to date. And there are many who will not be disappointed, since this book will appeal to a wide range of readers.

Apart from a few basic equations (such as Einstein's famous relationship between mass and velocity) there is an absence of mathematics or formulae. In their place is the author's lucid language which is a delight to read as English, apart from the enormous amount of information packed into the 200 pages.

The chapter headings will give a good impression of the range of material covered: The Electron: The Thermionic Valve: The Cathode Ray Tube: The Klystron: The Positive Grid Oscillator and the Magnetron: The Cyclotron: X-Rays: Photoelectric Cells: The Electron Multiplier: The Application of Electron Technique to Television: the Electron Microscope: The Mass Spectrograph: Electricity in Gases. The author sketches the historical background behind each device, though he leaves the reader with the latest techniques. The chapters on the Magnetron, Cyclotron and Mass Spectrograph contain the results of wartime and postwar researches only previously described in more highly technical papers. The author has also been at pains to instil certain fundamental principles, such as the circular motion of an electron traversing a magnetic field, necessary to the clearer understanding of the practical devices described.

The book is liberally illustrated with photographs and diagrams. The latter, perhaps, have been almost over-simplified in that sectional, rather than perspective, views are mostly adopted. These are not always the clearest for introducing unfamiliar instruments—for example the Klystron, Cyclotron, etc.

This book will be of value even to those already acquainted with many applications of electronic science, and a well balanced survey of such an important subject is something new in more than one sense.

While hesitating to point to omissions in a small work so crammed with valuable information, we would like to ask Dr. Britton to remember the name of J. L. Baird in the Television chapter of any future editions.

T. H. BRIDGEWATER

REVIEWS

Principles of Electrical Engineering

T. F. Wall, D.Sc., D.Eng., M.I.E.E. George Newnes, 40s.

The title page describes this book as: "A Comprehensive Work covering the Principles of Heavy-current and Light-current Engineering Practice: also covering the requirements of the B.Sc. (Engineering), A.M.I.E.E., and Higher Examinations in this subject." It is no criticism of the contents of the book to say that this publisher's claim is unfortunate and clearly misrepresents the author's intention. A single book cannot be expected to cover even the whole of the electrical engineering ground required for a degree course.

More emphasis than has been usual in the past is given to those fundamental aspects of the subject that are common to heavy and light current engineering and space is made for them by omitting much that has hitherto been considered essential to a degree course. Thus conduction in gases is treated with unwonted, but welcome, thoroughness and is introduced with a brief discussion of the structure of the atom. The subject is rightly given as much space as conduction in solids, and Ohm's law is thereby made to appear, as it really is, not as a universal truth found by experiment, but as the statement of a property possessed by certain specific conductors. Considerable prominence is given to many aspects of the electric field and the theory of dielectrics, while discussion of magnetism, more often given pride of place, is postponed to the sixth chapter. As the principles of the electric generator and the electric motor are not common to both heavy and light current electrical engineering they are discussed in no more than a few pages. Similarly the transformer is mentioned only for the purpose of illustrating the principle of mutual induction. The propagation of electrical energy, both in conductors and through space, is, on the other hand discussed in considerable detail. All this is fully justified by the author's evident intention, whatever the title page may say.

Alternating currents, both sinusoidal and non-sinusoidal, single-phase and three-phase systems, oscillating circuits, the use of complex quantities all have their place in the book and are treated more in terms of fundamental principles and less of specific applications than is usual in a degree course. The danger of such treatment lies in the difficulty of always distinguishing between what is of basic importance and what of only academic interest. In the present reviewer's opinion Dr. Wall keeps on the right side of the dividing line between these two and so the book should give the student a deeper insight into the nature of his subject than other, possibly more practical, but certainly more superficial books would do. Nevertheless the student who relies on this book alone will miss much that he will need in the electrical engineering world. But though he should build the superstructure of his knowledge with materials obtained from other sources, he will do well to build on Dr. Wall's book as a foundation.

The opening chapter is concerned with fundamental units, a subject on which there are still many misapprehensions that will not, I fear, be wholly dispelled by Dr. Wall's treatment. To say on p. 6, for instance, that the dimensions of μ and ϵ are not separately known is but to repeat a long established error that a little thought ought to dispel. It obscures the fact that an arbitrary choice of four fundamental dimensions can, and must, be made in electrical theory and that, after the choice has been made, the dimension of both μ and ϵ *are* separately known. Again the MKS system, to which too little prominence is given, is presented in such a way as to suggest that the MKS unit of permeability had been derived from the arbitrary choice of 10^5 dynes as the unit of force. In fact it was the other way about. Unit permeability was arbitrarily chosen as 10^7 that of free space and thereby the electrical MKS units were made to equal the practical ones. I suspect that Dr. Wall is not quite reconciled to the fact that permeability is a dimensional quantity. Few, if any, of us were taught in our youth that one can construct a consistent electro-magnetic system of units in which any quantity of permeability is arbitrarily called unity, provided arbitrary units are also allocated to not more than three other quantities. We were told instead that three primary units suffice for all purposes. We had to play ostrich to the fact that, by assigning unit value both to the permeability and the permittivity of free space, not three but five primary units were in use: one too many instead of one too few.

The mathematical treatment is always elegant and within the capacity of the undergraduate, though expressions are sometimes reached overswiftly, as for instance equation 24 on p. 63, where one extra line would help to explain the sudden appearance of a two thirds power. But in the mathematical formulae one departure from convention is unfortunate. Vector quantities are represented by Gothic script instead of by the heavy type that has been standardised by the B.S.I.

These, however, are minor blemishes. They do little to detract from the value of the work for the student who attaches importance to sound theory. The style of the writing is clear and attractive; the illustrations are excellent.

R. O. KAPP

BOOKS TELEPHONE: EUSTON 4282 (5 lines)

Books on all branches of RADIO and ELECTRICAL ENGINEERING

A good selection always available. Books reviewed or mentioned in this Journal can be supplied. If not in stock, they will be obtained from the Publishers when available.

Continental and American works unobtainable in this country can be secured in the shortest possible time.

SECOND-HAND BOOKS: 140 Gower Street, W.C.1.

Large stock always available. Books sought for and reported free of charge. Large or small collections bought.

LENDING LIBRARY

SCIENTIFIC AND TECHNICAL

Annual Subscription from One Guinea

Prospectus post free on request.

Bi-monthly List of New Books and New Editions post free to subscribers regularly.

THE LIBRARY CATALOGUE revised to December 1943, containing Classified Index of Authors and Subjects. Demy 8vo. Pp. 928.

To subscribers, 12s. 6d. net
To non-subscribers, 25s. net } Postage 8d.

SUPPLEMENT, 1944 to December 1946. Demy 8vo. Pp 168.

To subscribers, 2s. 6d. net
To non-subscribers, 5s. net } Postage 4d.

H. K. LEWIS & Co. Ltd.
LONDON: 136 GOWER STREET, W.C.1

USEFUL BOOKS

RADIO FREQUENCY MEASUREMENTS BY BRIDGE AND RESONANCE METHODS
By L. HARTSHORN, *D.Sc., A.R.C.S., D.I.C.*
Demy 8vo. 265 pages. 99 illustrations. 21s. net.

TIME BASES
(SCANNING GENERATORS)
Their design and development, with Notes on the Cathode Ray Tube.
By O. S. PUCKLE, *M.I.E.E.*
Demy 8vo. 204 pages. 124 figures. 16s. net.

THE PATH OF SCIENCE
By C. E. KENNETH-MEES, *D.Sc., F.R.S.*
With the co-operation of
JOHN R. BAKER, *M.A., D.Phil., D.Sc.*
Demy 8vo. 250 pages. 6 figures. 18s. net.

MATHEMATICS APPLIED TO ELECTRICAL ENGINEERING
By A. G. WARREN, *M.Sc., M.I.E.E., F.Inst.P.*
Demy 8vo. 400 pages. 132 figures. 21s. net.

CHAPMAN & HALL, LTD.
37, Essex Street, London, W.C.2.

ABSTRACTS OF ELECTRONIC LITERATURE

MEASUREMENT

Functional Analysis of Measurement
(I. F. Kinnard)

Through the use of functional analysis any measurement scheme can be considered as being composed of not more than three functional parts i.e. primary detector, intermediate means and end device, either indicator, recorder or controller. Thus a great variety of equipment may be reduced to a few fundamental types. The advantages of standardisation of instrument components as far as possible are discussed and several examples of the functional analysis and classification of instruments are given.

—*Elect. Engg.*, January, 1947, p. 11.*

Measurement of Small Direct Currents
(C. E. Nielson)

Small direct currents below 10^{-8}A may be measured by means of vacuum tubes, and the grid current characteristic of such tubes is critical in fixing a lower limit to the currents measurable. The usefulness of types 38, 954 and 959 tubes for such purposes is investigated, and considerable data is presented, primarily showing the dependence of grid current upon applied potentials, and secondarily giving information on the corresponding plate current characteristics. Grid currents less than 10^{-15}A in the 959 tube are reported, associated with stability comparable with that of specially designed electrometer tubes.

—*Rev. Sci. Inst.*, January, 1947, p. 18.

A Meter for High Voltage Measurement
(H. Alfven and S. Eklund)

A high voltage meter employing a capacitance voltage divider is described, which can be used for A.C. and D.C. measurements when combined with a special grounding device. The high voltage source is connected to one electrode of the condenser network, the other electrode being connected to a low voltage electrostatic voltmeter, one pole of which is earthed. It is shown that the calibration constant for this type of meter remains approximately constant for various ranges of voltage. The construction of an instrument covering the range 2-100 KV is described. Applications and further improvements are discussed.

—*Rev. Sci. Inst.*, October, 1946, p. 353.

Pulse-Type Tester for High-Power Tubes
(E. C. Easton and E. L. Chaffee)

Motor-driven 5-r.p.m. commutator in simple trigger circuit causes ignitron to fire and apply high-voltage pulse to grid of tube being tested. Resulting grid and plate voltage and current pulses are measured on high-persistence cathode ray tube by means of calibrating spot.

—*Electronics*, February, 1947, p. 97.

Wide-Angle Phase Modulator
(H. K. Bradford)

Technique for phase modulating a crystal-controlled carrier, whereby two components of fixed phase difference are amplitude modulated and added to give the output, is described. Circuit can be used to give frequency modulation, or modified to give amplitude modulation.

—*Electronics*, February, 1947, p. 101.

Balanced Amplifiers
(F. F. Offner)

Push-pull impedance-coupled amplifiers have wide applicability in electronic instrumentation. Four gain factors are required to completely describe their performance. Of these factors, one should be large and the others as small as possible. These characteristics are obtained by in-phase feed-back, applied properly. A number of circuits suitable for various applications, are described.

—*Proc. I.R.E.*, March, 1947, p. 306.

Improvement of the Characteristics of Photo-Voltaic and Photo-Conductive Cells by Feedback Circuits
(E. S. Rittner)

Photo-voltaic and low resistant photo-conductive cells are, in general, characterised by high current sensitivity, which decreases as the load resistance is increased. This decrease in sensitivity may be avoided by maintaining a constant voltage across the cell and a description is given of two stable electronic circuits which were designed to accomplish this and serve as D.C. amplifiers. These electronic circuits comprise a single stage and a two stage amplifier respectively and both circuits employ feed-back to obtain a nearly constant voltage across the photo-cell. The characteristics of the amplifiers are shown graphically.

—*Rev. Sci. Inst.*, January, 1947, p. 36.

Graphical Analysis of Cathode-Biased Degenerative Amplifiers
(W. A. Huber)

A method of graphical analysis by which it is possible to predict the performance of cathode-follower and plate-resistance-loaded, cathode-degenerative triode amplifiers is given. The method is based on data supplied by the average plate characteristic curves. Several numerical examples are given illustrating various points of the text. It is shown that the graphical method may be advantageously used in design problems requiring the selection of the correct cathode resistor for a given signal input and bias condition.

—*Proc. I.R.E.*, March, 1947, p. 265.

* Abstracts supplied by the courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester

A Heavy Current Contact for Radio-Frequency Use
(A. J. Maddock)

A description is given of a contact device of the high-pressure small area type, capable of carrying 75 A. at 20 Mc/s. and 150 A. at power frequencies. While relative movement and rotation is provided between the various parts of the assembly, all contacts are of the high-pressure type and there are no flexible leads or springs carrying current. Curves of temperature rise of the contact above the circuit temperature for different electrical and mechanical loadings show that above a spring loading of about 3 kg. the temperature rise becomes almost independent of the total force. Examples of the use of this device are mentioned with reference to improvements in the design of switches for large variometers or coupling coils.

—*Jour. I.E.E.*, (Pt. 3) Jan. 1947, p. 52.

The Servicing of Radio and Television Receivers
(R. C. G. Williams)

The service organisation for the maintenance and repair of radio and television receivers has developed with the growth of the industry. The paper opens with a reference to the fundamental concepts of "working life" and service, and after a brief historical review examines the basic responsibility of a service organisation and the methods by which this may be fulfilled. Personnel and equipment problems are next considered and analysed, and a typical service department is described. Consideration of the inter-relationships between service and design is followed by a discussion of the service aspects of television and export as prominent post-war problems. The paper concludes with some notes on future development.

—*Jour. I.E.E.*, January, 1947, p. 11.

Recent Developments in the Field of Magnetic Recording
(S. J. Begun)

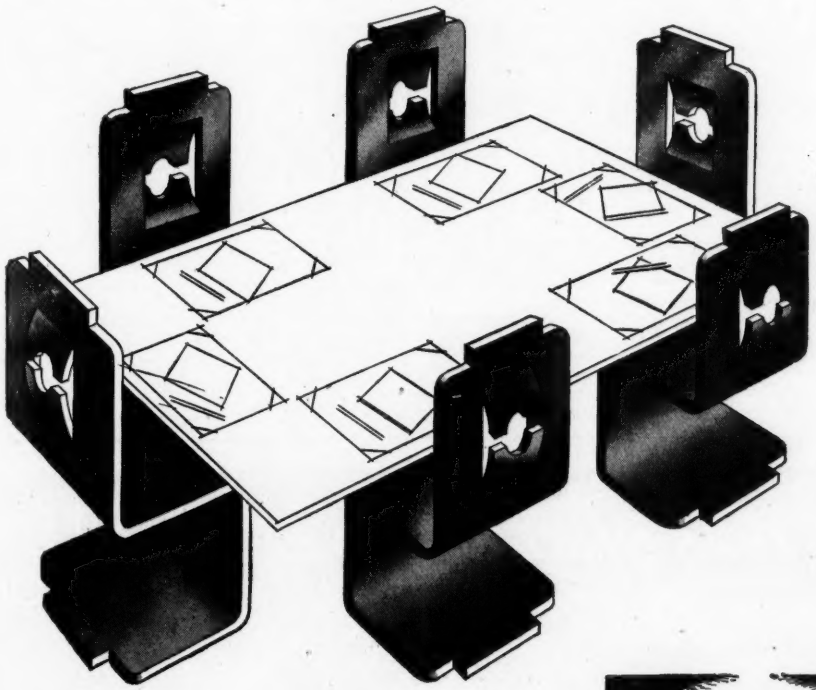
New magnetic recording media have been developed during recent years which will widen substantially the field of application for magnetic recording equipment. Probably most outstanding among the new recording media is the non-ferrous wire or tape, plated with a thin layer of nickel-cobalt alloy, and the paper disks and tapes coated with a dispersion of magnetic powder.

It might be of particular interest to the motion pictures industry that the coated recording media can be perforated to obtain synchronisation between picture and sound. It is also possible to apply the magnetic coating directly to the film base.

—*Jour. S.M.P.E.*, January, 1947, p. 1.

next for discussion please...

The beauty of Spire Fixing (yes, we said 'beauty' and meant it) is that it isn't fixed. It is a principle that can be adapted to almost any light assembly problem. There are already over 350 various Spire Fixings and fresh ones coming along almost daily. What can Spire do for you? Isn't there some fumbling, fiddling, fastening problem it could tackle? A blind or awkward assembly perhaps? An assembly that won't 'stay put'? There may be an existing Spire solution — if not, we'll design one. Can we discuss it?



THAT'S fixed THAT! The NU Types of Spire Fixings make blind assembly quick and certain. The NU is slipped over the edge of the sheet and the extrusion snaps into the bolt hole. If the bolt hole is some distance from the edge of the component a slot may be punched near the hole to enable the Spire Fix to be slipped into position. The NU fix gives a self-aligning assembly, the amount of float being varied as desired by altering the size of the bolt hole.

Spire Regd. ★ A BETTER way of fixing

SIMMONDS AEROCESSORIES, LIMITED, TREFOREST, GLAMORGAN.

9

A Note on the Twin Triode Phase-splitter—By R. L. Gordon

In his article on the Twin Triode Phase-Splitting Amplifier in the February 1947 issue of ELECTRONIC ENGINEERING, Mr. J. D. Clare concentrates on the generation of accurate push-pull signals for audio-frequency work. As he points out, the frequency response in the bass end of the audio spectrum depends on the components R and C (Fig. 2), and however big the time constant is made, it is obvious that the response will be zero at zero frequency.

A simple modification to the circuit as given, however, will extend the frequency response to zero cycles per second, and can also be arranged to increase the output swing at the two anodes. The gain is slightly reduced: this however is not always a serious objection, and in cathode ray tube deflector circuits, for example, is of negligible importance.

The modified circuit is shown in the diagram. It will be seen that, whereas in the circuit shown by Mr. Clare only the first triode is a cathode follower, now both valves are effectively behaving as such. The grid of V_2 is now anchored, not to the anode of V_1, but to a tap on a D.C. potentiometer, so that the response drop due to Mr. Clare's RC time constant is eliminated. Since V_2 is now a cathode follower, the effective grid base of the valve is lengthened according to the exact value of R_b: in any case larger voltage swings at the grid can be accommodated. The cathode negative feedback, however, reduces the possible gain.

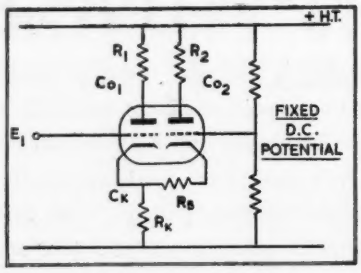
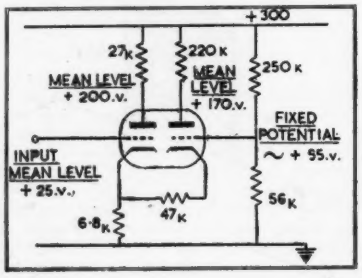


Fig. 1 (above). Fig. 2 (below)



Analysis of the circuit shows that the theoretical condition for balanced push-pull output is

$$\frac{e_{01}}{e_{02}} \simeq \frac{-R_1}{R_2} \times \frac{1+g_2(R_B+R_K)}{g_2R_K} = -1$$

if $\dfrac{R_2}{R_1} = \dfrac{1+g_2(R_B+R_K)}{g_2R_K}$

or, if $g_2R_K >> 1$

$$\frac{R_2}{R_1} = \frac{R_B+R_K}{R_K}$$

The percentage change in the balance for a given percentage change in g_2' is now given by:

$$\frac{\partial(e_{01}/e_{02})}{e_{01}/e_{02}} = -\frac{1}{1+g_2'(R_B+R_K)} \frac{\partial g_2'}{g_2}$$

which is improved by a factor

$$\frac{1+g_2'(R_B+R_K)}{1+g_2'R_K} = \frac{R_B+R_K}{R_K}$$

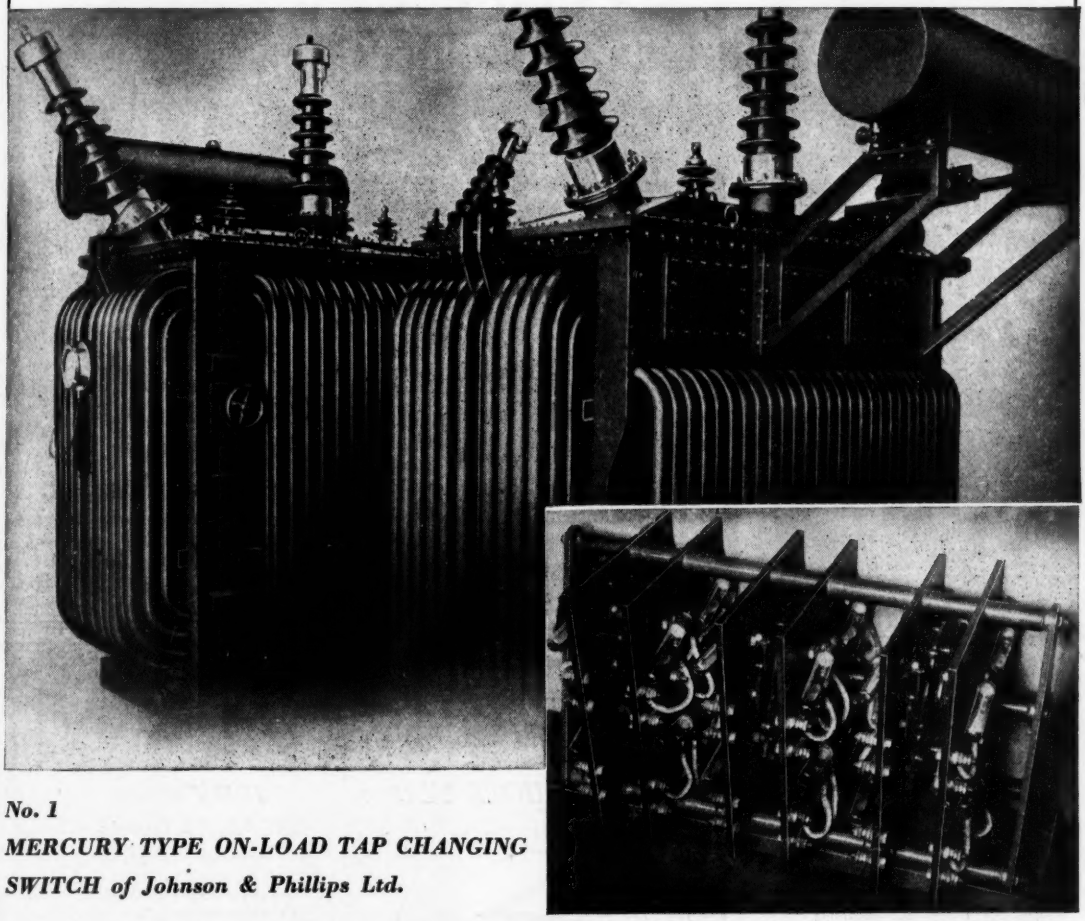
if $g_2'R_K >> 1$

A practical circuit as shown in the second diagram has a gain of about 4, and each anode will handle a peak-to-peak swing of the order of 150 volts, which is sufficient to deflect fully the spot of a C.R.T. of the 3 in. type with normal final anode potential.

It is appreciated that for audio-frequency work Mr. Clare's circuit has more to recommend it, particularly in simplicity. The modification may, however, be of interest to readers, particularly in view of its D.C. response characteristics.

P.S. Surely there is a minor misprint in the article: in the "Symbols Used" the effective mutual conductance should read $g_1' \dfrac{g_1R_{a1}}{R_{a_1}R_1}$ and $g_2' \dfrac{g_2R_{a2}}{R_{a_2}R_2}$ respectively?

WHERE THEY USE BAKELITE LAMINATED



No. 1
MERCURY TYPE ON-LOAD TAP CHANGING SWITCH of Johnson & Phillips Ltd.

Because the tapping switches are immersed in transformer oil at high temperatures, Messrs. Johnson & Phillips Ltd. have adopted BAKELITE Laminated as the insulating material most suitable for standing up to these onerous conditions. The insulating properties of BAKELITE Laminated are good, and the material not only resists the action of heat and oil, but is also light in weight and is easily fabricated. It is available in sheets up to 4 inches thick, and rods and tubes.

The switch illustrated is designed for use with power transformers up to 11 kV working voltage.

TREFOIL
BAKELITE PLASTICS
REGD. TRADE MARKS

Essential Materials for Essential Work

BAKELITE LIMITED · 18 GROSVENOR GARDENS · LONDON · S.W.1

T109

AND NOW
A.C./D.C.

20-25 WATT UNIVERSAL AMPLIFIER-U885

Similar to our 30-watt A.C. model and fitted with latest control panel carrying mic., gram. and tone controls, mains switch, pilot lamp and special 3-position switch providing either change-over or mixer circuit for gram. and mic. Three-stage high-gain type having 4 valves in parallel push-pull in output stage, a total of 10 valves.

TRIX
Quality SOUND EQUIPMENT
Full details of this and other models sent on request.

THE TRIX ELECTRICAL CO. LTD.
1-5 MAPLE PLACE, TOTTENHAM COURT ROAD, LONDON, W.1
TELEPHONE: MUSEUM 5817 GRAMS & CABLES: TRIXADIO, WESDO, LONDON

EUREKA
REGD.
& NICKEL-CHROME
RESISTANCE WIRES & TAPES

MOLYBDENUM
WIRES, TAPES & RODS
for
ELECTRIC FURNACES
LAMPS & VALVES

and
VAC-STEEL
PLATINUM CLAD
GAS-FREE NICKEL
WIRES : TAPES : BARS & MESH

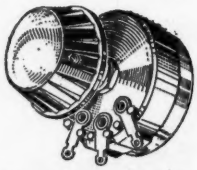
EXACT TO SPECIFICATION

LET US QUOTE YOU

VACTITE WIRE COMPANY
VACTITE
—REGD.—
LIMITED

WAVERLEY WORKS,
75, ST. SIMON STREET,
SALFORD, 3, LANCS.
Telephone: BLACKFRIARS 9831
Telegrams: VACTITIC, SALFORD

RELIANCE
POTENTIOMETERS



Types T.W. and S.G.

T.W. Wire-wound track—
Rating : 5 watts (linear) Max.
3 watts (graded) ,,
Ranges : 10-100,000 Ω Max. (linear)
100-50,000 Ω Max. (graded)
100-10,000 Ω Non-inductive

S.G. Composition track—
Rating : 1 watt maximum.
Range : 2,000 to 2 megohms.

Characteristics : (either type)
Linear, log., semi-log, inverse log., non-inductive, etc.

Write for full details to :
RELIANCE
Manufacturing Co. (Southwark) Ltd.
Sutherland Road, Higham Hill,
Walthamstow, E. 17
Telephone : Larkswood 3245

Partridge News

INDIVIDUAL DESIGN

PARTRIDGE *Precision Built* TRANSFORMERS wound to suit individual requirements now incorporate:—
Silver-plated turret terminals giving a low potential drop and carrying up to 15 amps. Adequate room on each for easy soldering of several external circuit wires.

Firm clamping of the laminations by means of scientifically designed pressure die-castings.

Interlocked fixing feet providing alternative mounting.

AVAILABLE STOCK

A comprehensive range of mains and audio components is now available from stock, and we can despatch small quantities of these per return. We would stress that before ordering you send for our list detailing these components. Our stock range now covers almost all normal requirements, and by availing yourself of this service you will save the inevitable delay in the production of a special component. We shall be pleased to send you our stock list upon receipt of your address.

Telephone: Abbey 2244
PARTRIDGE
TRANSFORMERS LTD
76-8, PETTY FRANCE, LONDON, S.W.1.

TO
Chief Buyers
of
INDUSTRIAL
ORGANISATIONS

TELE-RADIO LTD

TELE-RADIO (1943) LTD. for high grade radio and electronic components. Suppliers to the Government, Services, Universities and Training Colleges, Local Authorities (for own use), Industrial Organisations, etc. Buyers requiring components in a hurry will find it quicker and more economical to phone PADdington 6116 (quoting official order number). Goods can be despatched usually same day.

TELE-RADIO DEVELOPMENT LTD. Suppliers to the Government of communication and electronic prototypes. Ample facilities available for development and construction where imaginative design and highest grade workmanship are of paramount importance.

Specialists in miniaturisation.

TELE-RADIO (1943) LTD.,
177 Edgware Road,
LONDON, W.2.
Telephone : PADdington 6116

A range of DEPENDABLE Transformers & Chokes–

COMPRISING

45

MAINS TRANSFORMERS

27

SMOOTHING CHOKES

FOR IMMEDIATE DELIVERY from STOCK

These fine Transformers and Chokes fulfil every normal laboratory, radio and industrial requirement : but if some unusual need demands a special design, this can usually be made and delivered within a few weeks. All these Transformers and Chokes are made to meet the requirements of all relevant Government specifications ; the name Gardners is synonymous with the highest standards of design, materials and workmanship.

Resident A.I.D. inspectors available.

★ WRITE FOR LISTS AND SPECIFICATIONS

GARDNERS

"SOMERFORD"
TRANSFORMERS & CHOKES

Gardners Radio Ltd. • Somerford • Christchurch • Hants

Miniature or Midget

ACTUAL SIZE

HIVAC

THE SCIENTIFIC VALVE

BRITISH MADE

NEW TYPES FOR

MIDGET RECEIVERS
HEARING AIDS
METEOROLOGICAL INSTRUMENTS
ETC.

HIVAC LIMITED Greenhill Crescent, Harrow on the Hill. Middx. *Phone* HARROW 0895

The comprehensive range of vibration equipment developed by the de Havilland Enterprise, and the wide experience of de Havilland engineers in this field, are now available to all branches of industry.

One of a range of high-grade amplifiers for vibration and fatigue testing.

DH ENTERPRISE

DE HAVILLAND

Enquiries should be made to
de Havilland Propellers Ltd. (Dept. EE)
Hatfield Aerodrome, Hertfordshire
Telephone : Hatfield 2300

★

FOR MEN ONLY *interested in*

Seamless, one-piece, metal bellows . . . formed in one continuous operation by a process unique in this country, with a uniformity of wall-thickness unobtainable by any other method . . . No annealing, no spinning, no localised strain or thinning ; none of the limitations of metallic diaphragms.

These bellows, though no thicker than paper—the walls range from 4/1000" to 7/1000"—are tough, resilient, and combine the characteristics of a coiled compression spring, a packless gland, and a non-ferrous hermetically sealed container. Every bellows is pre-tested during forming and has a high degree of uniformity of life, performance and reliability in operation. Available in root diameters of ⅜" to 3", outside diameters ⅞" to 4½".

Write for the Hydroflex Brochure X

★

Refrigeration
Temperature Control
Air compressors
Water pumps
Paper machines
Gland seals
Thermostatic & pressure operated appliances

Drayton Hydroflex METAL BELLOWS

Drayton Regulator & Instrument Co., Ltd., West Drayton, Mdx.

Dainite
MOULDED RUBBER PARTS
Inquiries are invited for special mixings for Electrical, Motor Car and General Trade purposes
THE HARBORO RUBBER CO. LTD. MARKET HARBOROUGH

EME for your individual requirements in ELECTRONIC EQUIPMENT

EXAMPLE—A Current Impulse Generator giving a Rectangular Wave Form with Amplitude, Frequency and Duration Control.

THE ELECTRO MEDICAL EQUIPMENT LABORATORY CO., LTD.
247-9 Burnt Oak Broadway, Edgware, Middlesex
Telephone : EDGware 8121

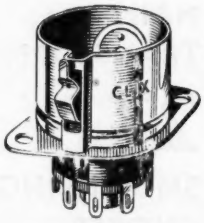
CLIX

Radio and Television Components are used by all the leading set manufacturers

★

No. 3 *Points of low contact resistance in modern circuit design.*

Easy insertion of valve. Firmly retained. Easy withdrawal. Standard fixing centres 1⅛". Hole diameter ⅛".



Clix-type B8A Valveholders

BVA Standard Dimensions

Designed to meet the requirements of the new all-glass type B8A Valves. Moulded body . . Plated saddle . . Screen . . and Sockets, ensuring extremely low contact resistance. A valve-retaining latch specially suitable to these new all-glass valves. A feature exclusive to Clix B8A Valveholders. *Clix Valveholders are adequately protected by British and Foreign Patents.*

BRITISH MECHANICAL PRODUCTIONS LTD.
21 BRUTON STREET, LONDON W.1 *Telephone : MAYfair 5543*
Foremost in Valveholder design

METAL WORK! *FOR THE RADIO TRADE*

PRECISION BUILT
CABINETS and CHASSIS
BY
CHASE PRODUCTS
(ENGINEERING) LTD.
27, PACKINGTON ROAD, LONDON, W.3
ACORN 1153/4

BRAY CERAMIC INSULATORS

for L.F. and H.F. Components, also capacitor dielectrics

made by
GEO. BRAY & CO., LTD. LEEDS, 2
Established 1863 Phone Leeds 20981

CLASSIFIED ANNOUNCEMENTS

The charge for miscellaneous advertisements on this page is 12 words or less, 5/- and 4d. for every additional word. Box numbers count as four words, plus 1/- extra for replies. Remittance should accompany advertisement. Cheques and P.O.'s payable to Morgan Brothers (Publishers) Limited, 28 Essex Street, Strand, London, W.C.2. Replies to box numbers should be addressed as above, marked "Elec. Engg." Press date: 10th of month for following issue.

FOR SALE

IN STOCK. Rectifiers, Accumulator Chargers, Rotary Converters, P.A. Amplifiers, Mikes, Mains Transformers, Speakers of most types, Test Meters, etc. Special Transformers quoted for.—University Radio, Ltd., 22, Lisle Street, London, W.C.2. GER. 4447.

APPROX. 50 Rotary Convertors, heavy duty. 12v. D.C. input. Output 500v. 50 ma. min. Also 275v. 110 ma. min. 25s. each. Box 036, "Elec. Engg."

APPROX. 200 Rotary Convertors. 12v. D.C. input. Output 480v. at 40 ma. or 400v. at 80 ma. min. Some complete with gear boxes and spark suppression filters. 17s. 6d. each. Box 037, "Elec. Engg."

EX-R.A.F. Loran sets with 5-in. electrostatic C.R.T., with time base. 26 valves, including 6SN7, 6H6, 6SJ7, and calibrated 100 kc. crystal. Suitable for conversion to oscillograph, £10. Apply Box 050, "Elec. Engg."

ELECTRONIC ENGINEERING, March 1942 to June 1947. Five missing. Offers James, Way-end, Eastnor, Ledbury.

PHOTO-ELECTRIC CELLS, Se/Te on gold-alloy, supersensitive to light, gas-filled, permanent, operate a relay by light, either direct or through one-valve amplifier; also reproduce speech and music, etc., perfectly from sound track of films; large tube, 3½ in. from glass top to valve-pin base, 1 in dia., 38/-; same type, 2½ in. long, 35/-; small tube, 2 in. from top to terminal base, ⅝ in. dia., 30/-; miniature cell, glass top to cap base 1 in. overall, ½ in. dia., thin flex leads, 28/-. All cells operate on 40-100 volts. Wiring diagrams for relay and film sound amplifier free.

NEW PRECISION OPTICAL SYSTEM, microscope lenses, producing very fine line of light from 6- or 12-volt 1-amp. lamp, for scanning film sound track direct into photo-cell, metal tube 1½ in. long, ⅜ in. dia., ⅜ in. focus, 52/-. Full directions free. Cefa Instruments, 38a, York Street, Twickenham, Middlesex (POPesgrove 6597).

LOUDSPEAKERS

LOUDSPEAKERS—We carry on. Sinclair Speakers, 12, Pembroke Street, N.1.

LOUDSPEAKER repairs, British, American, any make, moderate prices.—Sinclair Speakers, 12, Pembroke Street, N.1.

MISCELLANEOUS

WE WILL BUY at your price used radios, amplifiers, converters, test meters, motors, pick-ups, speakers, etc., radio and electrical accessories. Write, phone or call, University Radio Ltd., 22, Lisle Street, London, W.C.2. GER. 4447.

THE NAME TO NOTE for all kinds of radio and electrical metalwork to specification, modern rust-proofing, all shapes and sizes undertaken, and for tropical use. Components and sub assemblies executed to meet recognised wiring and material standards. Consultation, advice without obligation. Write: Department O1, Sea Rescue Equipment Ltd., Chiltern Works, Clarendon Road, Watford. Herts.

PHOTOGRAPHY BY BEHR will show your product at its best. Ask for illustrated list. 44, Temple Fortune Lane, London, N.W.11. SPEedwell 4298.

MONOMARKS. Permanent London Address. Letters redirected. Confidential. 5/- p.a. Royal Patronage. Write Monomark BCM/MONO4S, W.C.1.

WEBB'S Radio Map of the World enables you to locate any station heard. Size 40 in. by 30 in. 2-colour heavy Art Paper, 4/6, post 6d. Limited supply on Linen, 10/6, post 6d.—Webb's Radio, 14, Soho Street, London, W.1. 'Phone: GERrard 2089.

MORSE Practice Equipment for Class-room or Individual Tuition. Keys Audio Oscillators for both battery or main operation. Webb's Radio, 14, Soho Street, London, W.1. 'Phone: GERrard 2089.

RADIOGRAPHIC LTD., 66 Osborne Street, Glasgow C.1. MAIL ORDER SPECIALISTS. TX VALVES. 813, 110/-; 805, 110/-; 832, 79/6; 841, 21/-; 866/866A, 27/6; RX VALVES: 9002, 10/6; 9003, 10/6; VR150/30, 15/-; VR105/30, 15/-; 1625, 25/-; R1155A RX, £15 15s. plus carriage, with Jones plug and Mod. details; UX5 pin ceramic V/holders, 1/-; 500 K.C. plug in crystals with OSC coil, 9/6 each 100 PF. TX. var. condensers, 2/6 each; mod indicators type 2 (includes 500 microamp meter) £2; wavemeters W1252 22–30 mcs., W1239 39–50 mcs., lab., instruments, individually calibrated, £4 2s. 6d. each; Muirhead dial drives type 1, 13/6 each. Thermo-Ammeters 0–350MA. 2 in., 17/6 each; 16 Henries/200 ma., impregnated chokes, 10/-; Ferranti 3 ratio P.P. O/P Transformer OPMI(C), 7/6; Pyrex bowl type lead ins., 2/6 each; 1 in. ceramic standoffs, 7d. each; 18 in. ceramic strainers with guy pulleys, 1/10 each. TCC 4 mfd. 800v. jelly filled condensers, 4/6 each; 1 mfd. 2000v. Tested 4000v. Muirhead mica, 7/6 each. List available. It pays to keep in touch with Radiographic Ltd., 66 Osborne Street, Glasgow, C.1.

WE HAVE THE Largest Stock of English and American radio books in the country, including many now out of print. Write or call for complete list. The Modern Book Co. (Dept. E.E.), 1923/23, Praed Street, London, W.2. (PAD. 4185).

OFFICIAL APPOINTMENTS

BRITISH BROADCASTING CORPORATION invites applications from men (British) for the post of engineer in the Audio Frequency Section of the Research Department based in London. Candidates must possess a University degree in physics or electrical engineering or equivalent qualifications, and must have taken electrical communication as part of their training. A knowledge of electrical measurements, measuring instruments and electro acoustics and experience in microphone and loudspeaker technique is essential. An appreciation of problems of electrical reproduction as applied to music will be an advantage. The work includes research into microphones and loudspeakers and embraces all other aspects of audio frequency research, design and development. Preference will be given to a candidate with the ability to guide development work in drawing office and workshops. Salary on appointment will be dependent on qualifications and experience, and subject to favourable report will rise thereafter by annual increments of £30 to a maximum of £680 per annum. Applications stating age qualifications and experience should reach the Engineering Establishment Officer, Broadcasting House, London, W.1, within 14 days of the appearance of this advertisement.

UNIVERSITY COLLEGE, Southampton, invites applications for the post of Lecturer in the Technical Department, University College, Southampton, for City and Guilds Telecommunications up to Grade 5. Salary, Burnham scale. Further particulars may be obtained from the Technical Officer with whom applications should be lodged by September 6.

SITUATIONS VACANT

ELECTRICAL ENGINEERING manufacturers in the Midlands require engineers with specialist knowledge of electronic control circuits and equipment, must have studied communication engineering to degree standard or equivalent. Also have sound general experience in electrical and mechanical engineering and ample practical experience in industrial electronic engineering. Age 28 to 35 preferred. Reply Box 993, "Elec. Engg."

A.M.I.E.E., City and Guilds, etc., on "NO PASS—NO FEE" terms. Over 95 per cent. successes. For full details of modern courses in all branches of Electrical Technology send for our 112-page handbook —FREE and post free. B.I.E.T. (Dept. 337B), 17, Stratford Place, London, W.1.

ELECTRONIC ENGINEER for large industrial concern in north-west London. Applicant must have degree, or equivalent, in electrical engineering and sound theoretical knowledge of electronic control circuits and equipment. Age preferably under 30. Applicant should give full particulars of experience, qualifications, and salary required. Box 049, "Elec. Engg."

FERRANTI LIMITED require for Vacuum Physics Laboratory Physicists or Engineers, graduates or with equivalent qualifications, preferably with experience of electronic vacuum work or U.H.F. valves. Application forms from Personnel Manager, Ferranti Limited, Ferry Road, Edinburgh, 5.

REQUIRED—Test Engineer with knowledge of high power high frequency valve generators. Box 968 "Elec. Engg."

THE MULLARD RADIO VALVE CO., require a senior radio valve development engineer, degree in electrical engineering or physics essential. Experience in valve development and valve application is desirable. The salary will be in accordance with the Company's scale based on age, qualifications and experience. Applications in the first instance should be in writing addressed to the Works Personnel Officer, Mullard Radio Valve Co., New Road, Mitcham Junction, Surrey. Please quote reference "R.a."

FOREMAN required for coilwinding department of large engineering concern in London area. Suitable applicant must have experience of simple and multi-spindle machines and must be capable of controlling male and female labour. State age, experience and salary required to Box 072, "Elec. Engg."

PLANNING ENGINEER with experience of coil-winding. Applicant should be capable of complete layout of all types of coilwinding. State age, experience and salary required to Box 073, "Elec. Engg."

JUNIOR ENGINEER required for development of processes on radio components in London area. Higher National Certificate in electrical engineering or equivalent essential. Box 071, "Elec. Engg."

SENIOR ENGINEER required for the research and development division of a large London firm. First class technical qualifications essential and previous experience of the design and development of radio components is desirable. Write stating technical qualifications, experience, age and salary required to Box 070, "Elec. Engg."

LARGE FIRM in South West London engaged in development and manufacture of all types of electronic tubes, have vacancies for production engineers. Applicants must be between 25 and 35 years of age and should have University degree in physics or engineering or equivalent qualifications, together with engineering apprenticeship or experience and must be interested in production engineering associated with highly technical manufacture. The vacancies offer good opportunities for promotion to managerships of large manufacturing or engineering development groups in an expanding industry. Previous experience in electronic tube industry is not essential. Reply giving full details to Box 480, L.P.E, 110 St. Martin's Lane, W.C.2, quoting the reference "S.a." These vacancies have been notified to our employees.

PRODUCTION DEVELOPMENT. Senior production engineer with specialised knowledge of production methods required by large light engineering company in London area. Suitable applicant should have experience of the design of tools and fixtures and knowledge of estimating. Write stating age, experience and salary required to Box 066, "Elec. Engg."

TELECOMMUNICATION ENGINEER required by Standard Telephones and Cables Ltd., North Woolwich, E.16, for the design and development of radio frequency testing equipment for carrier telephone and television cables. Applicants should possess an honours degree in engineering or physics and have had experience on comparable work. Salary up to £450 p.a. according to qualifications and experience.

SALES ENGINEER to specialise in automobile radio equipment. Experience in comparable field and adequate training essential; technical qualifications desirable. Age 25–30. Employment with leading London manufacturers. Excellent prospects. Salary according to experience. Box 075, "Elec. Engg."

NEW ZEALAND. Engineer/Salesman for cinema equipment company allied to leading circuit. First-class technical training and thorough experience on installation and servicing of sound film equipment essential; commercial experience, energy, initiative and organising ability will enhance prospects. Applications (in strict confidence) should give full details including experience, qualifications, age, whether married and present salary. Write Box 078, "Elec. Engg."

TELEPHONE APPARATUS Designer required by leading Company of telecommunication engineers situated in S.E. London district manufacturing for G.P.O., foreign and colonial administration. Write fully stating age, experience and salary required to Box 0/5482, A.K. Advtg., 212a, Shaftesbury Avenue, W.C.2.

CLASSIFIED ANNOUNCEMENTS (CONT.)

REDIFFUSION LIMITED have a vacancy in their development laboratory for a senior radio engineer capable of taking full responsibility development and design of transmitters varying powers and frequencies. Only live men with practical experience need apply to Manager, Rediffusion Limited, Broomhill Road, Wandsworth S.W.18, giving details of technical qualifications, salary expected and when available.

DEVELOPMENT AND RESEARCH Engineer required by radio manufacturers S.E. London district with commercial radio and television experience. Apply in strict confidence stating age, qualifications and experience to Box 077, " Elec. Engg."

TELECOMMUNICATION ENGINEERS wanted by large company in south-east London for development work on audio and carrier frequency equipment. Preferably Honours graduates in communication engineering or in physics, with at least two years' experience in telecommunication laboratory. Sound theoretical training essential. Salary according to qualifications and experience. Reply to Box 079, " Elec. Engg."

THE MEDICAL RESEARCH COUNCIL have vacancies in the Instrument Department at the National Institute for Medical Research, Hampstead, London, N.W.3, for: (a) Junior draughtsman-designer with drawing office and workshop experience; (b) Technical storekeeper, preferably with knowledge of service radio gear and able to make simple repairs and tests. Salary scale £218 (at 21) to £368 according to age and experience. Permanent superannuated posts. Apply to Administrative Officer, giving details of education and experience.

APPLICATIONS are invited for the position of Research Engineer to take charge of laboratories engaged in telecommunication cable development, electronics and general physics. Applicant should have high academic qualifications and extensive research industrial experience, as well as organising ability. Permanent position, superannuation scheme, 5-day week. Location North-west area. Apply Box 081, " Elec. Engg."

SITUATIONS WANTED

ARMY RADIO MECH., age 22½, seeks post in development or research work of television or electronic test equipment. Large knowledge and experience of highly complex switching equipment. Engaged at present on instructional work of pulse-modulated, multi-channel, U.H.F. system. Demob. February 1947. Box 069, " Elec. Engg."

RADIO ENGINEER, 34, Assoc. (Brit) I.R.E., A.I.R.E. Experienced in charge radio receiver development, prototype workshops and drawing office, seeks similar responsible position with progressive organisation. Box 067, " Elec. Engg."

DESIGN DRAUGHTSMAN seeks responsible situation in radio design or development. Well qualified and widely experienced. Box 068 " Elec. Engg."

ELECTRONIC ENGINEER and Physicist, F.P.S., with experience in Government departments and industry, seeks responsible position with reputable firm in or near London. Wide experience in development and production of electronic devices, cathode-ray tubes gas-discharge lamps, photocells, etc. Box No. 080, " Elec. Engg."

WANTED

URGENTLY REQUIRED. New or secondhand Mullard type E800 cathode ray oscillograph. Box 074, " Elec. Engg."

TUITION

RADIO AND RADAR. Technical courses for Postmaster General Certificates (M.N. Radio Officers), Ministry of Civil Aviation Certificates (Aircraft Radio Officers and Ground Engineers), Ministry of Transport Radar Certificates (M.N. Radar Engineers), City and Guilds Certificates in telecommunications and radio servicing, and Graduateship I.E.E. and Brit. I.R.E. Next session commences September 29, 1947. Prospects from Technical Office, University College, Southampton.

A.M.I.E.E. Examinations. Electrical engineer-lecturer (B.Sc. (Eng.) Hons. A.M.I.E.E.) specialises in private individual tuition. Vacancies for April 1948 exam. Personal or correspondence. Box 052, " Elec. Engg."

CRYSTAL PICK-UP

WITH *Unbreakable* CRYSTAL

The ACOS G.P.10 combines purity of reproduction with extreme reliability. A unique flexible assembly renders the crystal virtually unbreakable, while a needle-pressure adjustment is incorporated in the base. Resonance-free response from 50-8,000 cps. Output 1·5 v. at 1,000 cps. Needle pressure 1½ ozs. (adjustable). Vibration-free arm movement. Screened lead. Price in Great Britain 44/- (including P.T.).

Flexible coupling A protects crystal B against breakage. (Brit. Pat. 579,524. Pats. pend. abroad). Licensed by Brush Crystal Co. Ltd.

Obtainable only from Radio Dealers

COSMOCORD LTD
ENFIELD: MIDDLESEX

HERMETIC CERAMIC
AND
GLASS SEALS

EXCLUDE MOISTURE and DUST

ENQUIRIES ACCOMPANIED BY DETAILS INVITED

OXLEY DEVELOPMENTS Co, Ltd.
ULVERSTON

Varley

Products of Quality & Reliability

MAINS TRANSFORMERS
A.F. TRANSFORMERS
SMOOTHING CHOKES
THERMAL DELAY SWITCHES
POWER RESISTANCES

Made by

OLIVER PELL CONTROL LTD
CAMBRIDGE ROW, WOOLWICH, S.E. 18
Tel: WOOLWICH 1422

LONDON COUNTY COUNCIL

NORWOOD TECHNICAL INSTITUTE
KNIGHTS HILL, WEST NORWOOD
S.E.27
(*GIPsy Hill* 2268/9)
Principal: L. N. COOMBS, B.Sc.

SESSION 1947-48
Opening Date: 22nd September, 1947.
Enrolment: 15-19th September, 1947. from 6-8.30 p.m. daily.

EVENING COURSES IN TELECOMMUNICATION ENGINEERING
in preparation for
CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS
BRITISH INSTITUTE OF RADIO ENGINEERS (GRADUATESHIP)
including classes in
MATHEMATICS, TECHNICAL ELECTRICITY, TELECOMMUNICATION PRINCIPLES, RADIO AND TELEVISION

SHORT COURSES
Cathode Ray Tubes
Photo-Electric Cells
Ultra Short Waves
Electronics

DAY COURSES
It is hoped to arrange day classes for training in RADIO ENGINEERING. Particulars may be obtained from the Principal. (1217)

THE POLYTECHNIC
309 REGENT STREET, W.1

SCHOOL OF ENGINEERING

Head of School:
PHILIP KEMP, M.Sc.Tech., M.I.E.E., A.I.Mech.E.

FULL-TIME DAY COURSES are available in Electrical and Telecommunication Engineering. The courses, which extend over a period of four years, prepare for the National Diploma and Professional examinations and for the B.Sc.(Eng.), London.

Session 1947-8 begins on September 16th, 1947.

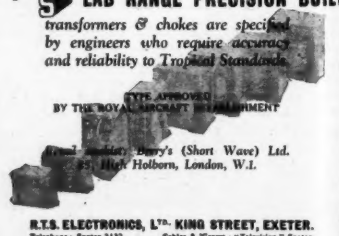
EVENING COURSES in these subjects commence on Monday, September 22nd. New students will be enrolled on 15th, 16th, and 17th September, from 6 to 8 p.m.

Prospectuses, giving full particulars of courses, fees, etc., may be obtained on application to the undersigned.

J. C. JONES,
Director of Education.

R T S "LAB" RANGE PRECISION BUILT

transformers & chokes are specified by engineers who require accuracy and reliability to Tropical Standards

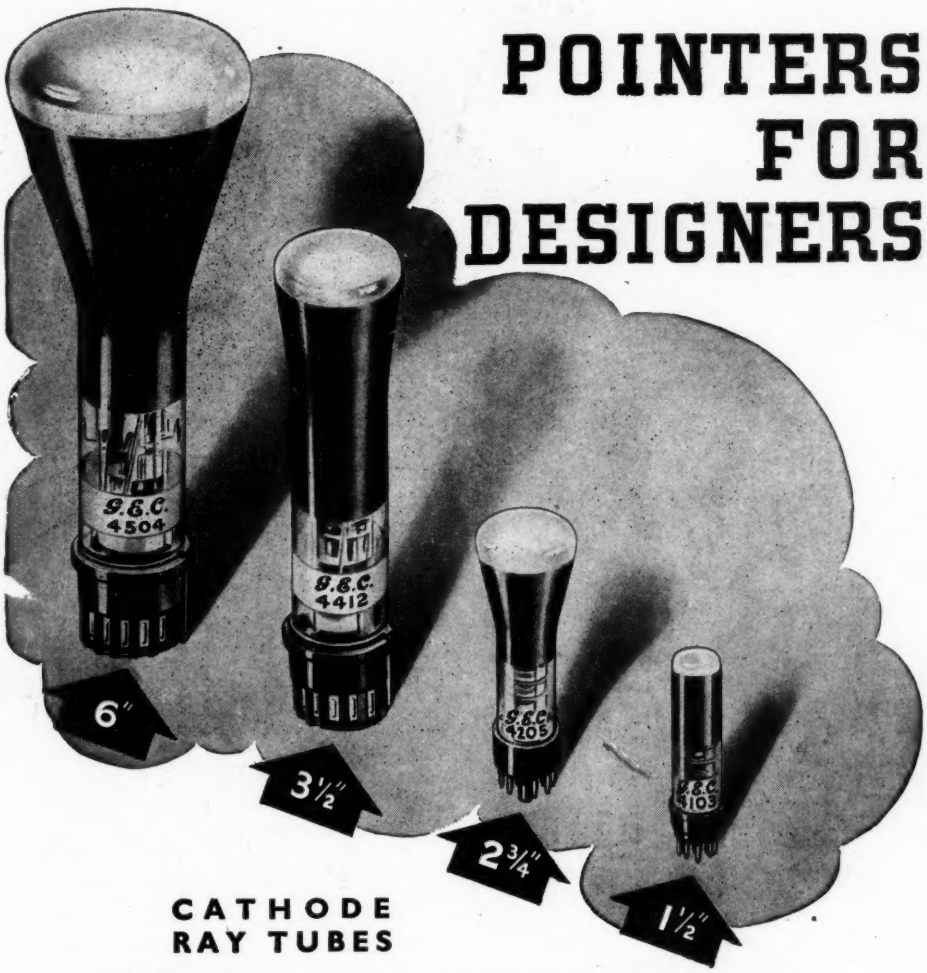


TYPE APPROVED BY THE ROYAL AIRCRAFT ESTABLISHMENT

Terms available: Barry's (Short Wave) Ltd. 65, High Holborn, London, W.1.

R.T.S. ELECTRONICS, LTD. KING STREET, EXETER.
Telephone: Exeter 3132. Cables & Grams: "Television," Exeter.

POINTERS FOR DESIGNERS



CATHODE RAY TUBES

The G.E.C. range of electrostatic industrial cathode ray tubes includes four screen sizes down to 1½" diameter. Widely used in measuring and similar instruments, their outstanding features include:—

- Brilliant screen traces and undistorted frequency response over a wide range.
- Screens for photographic recording or for producing sustained images, when specially ordered.

Electrostatic tubes for the maintenance of G.E.C. Television sets are also available. Other types will be in production shortly.

Detailed technical data sheets are available upon request.

Osram PHOTO CELLS — **G.E.C.** CATHODE RAY TUBES — **Osram** VALVES

Advt. of The General Electric Co., Ltd., Magnet House, Kingsway, W.C.2.

EDDYSTONE "640"

Communications Receiver

An efficient general purpose short-wave receiver, designed to meet the exacting requirements of Amateur-Band Communications.

Some salient features :—

Coverage 31 to 1.7 mc/s.

Electrical Band-spread throughout range.

Eight Valves (plus rectifier).

One R.F. and Two I.F. Stages.

Efficient Noise-limiter.

10, 20, 40, 80 and 160 metre Amateur Bands Calibrated.

Beat Frequency Oscillator.

Fly-wheel Control on Band-spread.

Vacuum mounted Crystal filter

Adaptor for Battery Operation.

The "640" has outstanding signal/noise ratio and extremely good image rejection. Provision for external connection of "S" Meter.

PRICE £42 - 0 - 0

PLUS P. TAX £9 - 0 - 7

THE "SHORT WAVE MAGAZINE" (June 1947) said :—

"The Eddystone '640' is a beautiful receiver and no operator who understands the amateur band requirement could fail to be impressed by it from every point of view. Because it is so good and the first British design worthy of the British amateur, we are glad to devote so much space to it."

(Reprints of the report, covering thorough tests made by the "S.W. Mag." technical staff, available on request from Webb's).

A specimen model may be seen at Webb's and we are now taking orders for rotational supply in August/September. Write for details of our registration scheme.

WEBB'S RADIO

WEBB'S RADIO, 14 SOHO STREET, OXFORD STREET, LONDON, W.1

Telephone : GERrard 2089. Shop Hours, 9 a.m. to 5.30 p.m., Sats. 9 a.m. to 1 p.m.

Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors, Morgan Brothers (Publishers) Ltd., 28, Essex Street, Strand, W.C.2. Registered for Transmission by Canadian Magazine Post.

947

d :—

rator
o be
good
e are

y the
bb's).

king
for

O

W.1

W.C.2.